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MAPPING AND MONITORING OF NORDIC VEGETATION AND LANDSCAPES

Conference proceeding

Eds. Anders Bryn, Wenche Dramstad &
Wendy Fjellstad

Viten fra Skog og landskap – 1/10

MAPPING AND MONITORING OF NORDIC VEGETATION AND LANDSCAPES

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FOREWORD

The conference «Mapping and Monitoring of Nordic Vegetation and Landscapes» took place in Hveragerði, Iceland from the 16th to the 18th of September 2009. The 105 participants from 15 countries contributed with 50 oral presentations and 19 posters. This special edition of «Viten», published by the Norwegian Forest and Landscape Institute, presents the conference proceedings, containing 32 articles and 13 posters. We wish to thank the participants for their contributions to both the conference and this report!

The Icelandic Minister of the Environment, Svandis Svavarsdottir, formally opened the conference. The Minister emphasised the importance of information on the environment, enabling politicians and management authorities to make well-informed choices to ensure that future development is sustainable. In that sense, she gave a short introduction to the three goals of the conference. Firstly, to share experience and knowledge about Nordic vegetation and landscape mapping and monitoring: methods, study design, content, implementation, analysis and the latest tools for processing map data. Secondly, to present scientific findings relevant for the private and public sector, the agricultural sector and nature management. Thirdly, to develop networks between different countries' scientific mapping communities. In particular, four topics were in focus:

- mapping of vegetation and landscapes,
- monitoring of vegetation and landscapes,
- cultural landscapes and management,
- landscape structure, processes and change.

Abstracts of all oral and poster presentations have previously been published by The Nordic Association of Agricultural Scientists (http: //www.njf.nu/site/seminarRedirect.asp?intSeminarID=424&p=1004).

The keynote speakers, Professor Donald A. Walker (University of Alaska, USA), Professor Helene Wagner (University of Toronto, Canada), Dr. Maria Luisa Paracchini (Joint Research Centre of the European Commission, Italy) and Senior Specialist Andrew Baker (Natural England, United Kingdom) gave four fascinating insights into issues of vegetation and landscape mapping and monitoring. We are grateful for their contributions to the conference.

During the conference, an initiative was taken to create a Nordic Working Group for vegetation and landscape mapping and monitoring within the International Association of Landscape Ecology (IALE) . This working group has been named NordScape and was established shortly after the seminar in agreement with IALE. The working group is in the process of establishing a new web-page which will keep us all updated on Nordic news regarding vegetation and landscape mapping and monitoring (see http: //www.iale.se/).

The initiative for the seminar was taken in 2006 in Stockholm during a Swedish seminar on vegetation mapping. Soon after a seminar committee was established, including members from all of the Nordic countries. Anders Bryn, Wenche Dramstad and Wendy Fjellstad (Norwegian Forest and Landscape Institute) represented Norway. Guðmundur Guðjónsson (Icelandic Institute of Natural History) and Guðrún Gísladóttir (University of Iceland) represented Iceland. Lars Andersson (Lantmäteriet), Anna Allard (Swedish University of Agricultural Sciences) and Margareta Ihse (Stockholm University) represented Sweden. Reija Hietala and Niina Käyhkö (University of Turku) represented Finland. Ole Hjorth Caspersen (Forest & Landscape) and Geoff B. Groom (The National Environmental Research Institute) represented Denmark. On behalf of the committee, we would like to thank the respective institutes for giving us the opportunity to arrange this conference. A special thanks goes to the Icelandic Institute of Natural History and the Norwegian Forest and Landscape Institute, who took care of most of the practical challenges of arranging the conference.

We are very grateful to the Nordic Council of Ministers, for financial support for the Conference and to The Nordic Association of Agricultural Scientists for administering the seminar registration, economy and home-page. We would also like to express our gratitude to The Soil Conservation Service (SCS) at Gunnarsholt, Iceland. SCS contributed to a splendid excursion and introduced us to the problems of erosion and revegetation efforts in Iceland.

The editors,

Ås, Norway, 8th June 2010

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INNHOLD

MONITORING LANDSCAPE AND VEGETATION IN THE SWEDISH NILS-PROGRAM

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Abstract

The NILS programme started in 2003 as an answer to the demands of monitoring information for the Swedish Environmental Protection Agency. NILS gathers environmental data in a strategic sample scheme nationwide. During five years all 631 permanent squares in 10 different strata are inventoried in a revolving scheme. The strategy is to conduct two parallel inventories, one in the field and one mapping the area using colour infrared aerial photos. Each square (of 5*5 km, with an inner square of 1*1 km where the detailed data is gathered) is inventoried in two ways, both as a field inventory and in aerial photos.

The strategy is to inventory a set of variables, (around 40 variables, with up to 44 subclasses). This very choice makes the programme compatible with a multitude of other inventories. As an example, the whole set of variables is now being converted into the European General Habitat Categories. It also makes it possible to extract variables for certain purposes, or to meet demands from different governing authorities. The aerial photo inventory is made in stereo models with digital images, using 0.5 m resolution in colour infrared which enables assessment of different vegetation and of different coverage, and also of the height of elements or even singles trees and bushes. The view from above also makes it possible to distinguish between patterns, both in the different growing layers and in the geomorphology of the land.

Data from NILS is used in many constellations in Sweden, examples are follow-up on the Habitats Directive for Europe, national reporting on small biotopes in the rural landscape, follow-up on a programme for valuable pastures and meadows, inventory on bumblebees and butterflies, and regional examples are inventories on the status of mires and waterways and other, to help with reporting on the 16 Environmental Quality Objects that Sweden has decided upon.

Introduction

The National Inventory of Landscapes in Sweden, (NILS) is a programme for monitoring the Swedish landscapes. Starting in 203, it was created to meet the increasing demands for information on national resources and environmental conditions. To supply a basis for planners and decision-makers of different levels, a continuous set of information from a permanent and wide sample is highly important (Bunce et al. 2008). As important, is the grasp of ecosystem processes and how they relate to the making of policies, as well as what features are possible to monitor with high accuracy, given the available techniques (Noss 1990, Geoghegan 1997, Stadt et al. 2006). The possibility to keep biological diversity at an acceptable level is a central objective all over Europe, as is stated by the convention of Biological Diversity and the 16 Swedish Environmental Quality Objectives (Council of Europe 2000, Ministry of Environment Sweden 2001, European Commission 2008a, 2008b).

Design

The definition of biodiversity often includes the organisational levels landscape, community or ecosystem, population or species and genetics (Noss 1990). This implies the need for a monitoring program to include structural and functional attributes of different spatial and temporal scales. The results from the NILS program is used in various different circumstances and in anticipation of this the set-up was made to allow for flexibility, to meet the various expectations (Inghe 2001, Ståhl et al. unpubl.). The design was selected so that data could be captured at different geographical scale and the sampling unit consists of the following parts (Figure 1). In 10 different strata, based on the regions in the rural statistics and the biogeographical regions (von Sydow 1988, Statistics Sweden 2001), 631 landscape squares were systematically placed over the nation. Each square is 5 x 5 km, and inside these extensive remote sensing-based and field-based inventories are made. An inner square of 1 x 1 km is mapped in detail using color infrared aerial photos in stereo models, together with GIS software for capturing the information and for all input data (e.g. map data and other inventories available as vector files). Inside the inner square field assessments are made on 12 permanent field plots consisting of concentric circular plots, the largest of 20 m in radius and 3 small satellite subplots around the center coordinates of 0.28 m in radius for species capture (Ståhl et al unpubl.). By this design a combination of inventory through the aerial photos and field is obtained, and several scale levels is covered. The aerial photos provide important information on landscape composition and the extent of land cover types (Skånes 1996, Allard 2003, Ihse 2007). The combination of all levels is very useful for monitoring purposes (e.g. Bunce et al. 2008).

Variables and classification

The NILS program uses another approach than most common programs, where a list of many straightforward, grouped and quantitative variables allows for adjusting the classification into many other, already existing classifications schemes. This is the case in both types of inventory, both from field and from aerial photos, using decision trees as compatible as possible to each other, described in the manuals for the program (Allard et al. 2003, Esseen et al. 2004). This paper concentrates on the information from the aerial photo inventory, where the set consists of 38 variables with up to 44 subclasses, which are summarised as their compatibility to the well-known concept of DPSIR, as adopted by the European Commission (e.g. 2003) in Table 1.

Data from NILS is used in many constellations in Sweden, examples of this are follow-up on the Habitats Directive for Europe, from the aerial inventory a national subset is reported on small biotopes in the rural landscape, from the field inventory NILS provides follow-up on a national inventory on valuable pastures and meadows, and an inventory on bumblebees and butterflies. Regional examples are inventories on the status of mires, lakes and waterways and other landscape features, to help with reporting on some of the 16 Swedish Environmental Quality Objects. As an example on the compatibility of the variables into other classifications schemes, the whole set of variables is now being converted into the European General Habitat Categories (Bunce et al. 2008) see Figure 2.

Figure 1: NILS's sampling design. 631 permanent landscape squares are placed into 10 different strata. Each unit is composed of a 5*5 km outer square with a 1*1 km inner square.

Table 1: The variable content in NILS (DPSIR-compatible).

Processes (Pressure)	**Structures (State)**
Ground disturbance	Vegetation structure
Hydrological changes	Dead wood and canopy structure
Grazing and mowing	Hydromorphological mire structures
Forestry	Linear and point features
Climate changes and air pollution	Soil properties
Habitats (State)	Species (Impact)
Forest	Vegetation-forming plants
Wetlands and shores	Epiphytes
Grassland and heath	Grasslands indicators (e.g. grazing impact)
Cliffs, rocks and other bare substrates	Game (droppings, etc.)
Man-made habitats (parks, etc.)	

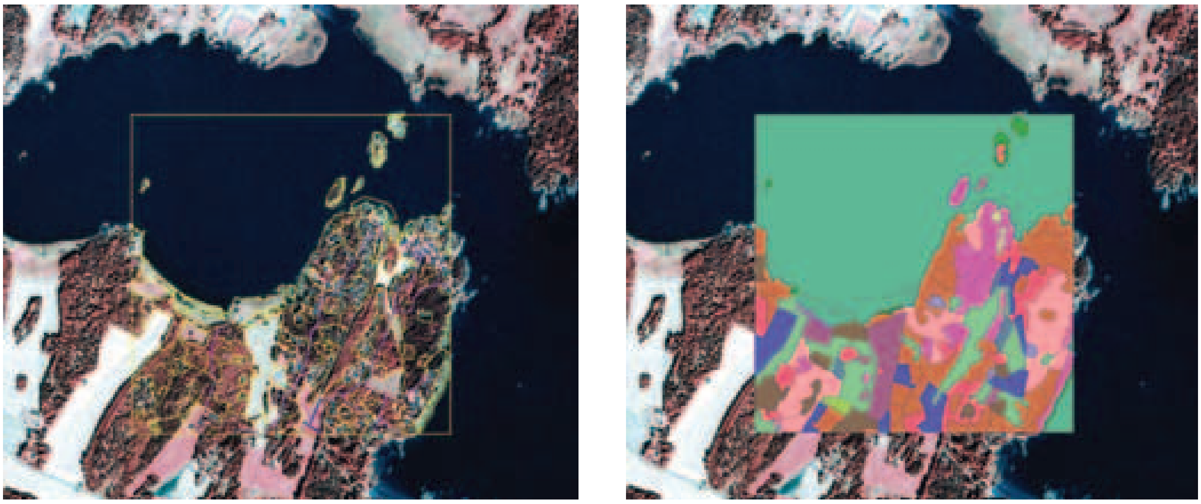

Figure 2: An example of conversion of the NILS data (from an SQL database, not seen here) into the European General Habitat Categories. The left picture shows the color infrared aerial photo with borders drawn for homogeneous landscape patches, and from all the variables measured and assessed in these the converted data is shown in the right picture.

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Geographical vegetation data of Lantmäteriet in Sweden

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Abstract

Lantmäteriet in Sweden executes vegetation mapping at a regional scale and administers vegetation data. CIR-sensitive aerial photographs are used as information source, with calibration through field work. The applied classification system is based on established scientific principles of vegetation classification. It is adopted to the applied mapping technique, and to preferences among major users. In fact, the degree of details in information is more limited by economy, than by the chosen technique. The digital vegetation data is arranged in separate covers: Polygon covers for vegetation and forest age class, one cover for natural line objects and one for natural point objects.

1 Background

In Sweden, vegetation mapping of larger areas started when Margareta Ihse (1975, 1978) laid the fundaments for interpretation of vegetation in aerial CIR photographs, and led the alpine vegetation mapping of the Swedish mountain range. This mapping was requested by the Swedish Environmental Protection Agency, as a basis for planning in the vast areas. Inspired by this, and with support from regional and local administration, Lantmäteriet started vegetation mapping in county of Norrbotten just before 1980, and has continued to produce vegetation maps and databases on regional agreements.

Ihse used the classification systems of Borg (1975) and Ryberg & Drakenberg (1976, 1978), with scientific base from Sjörs (1956) and other prominent works. These systems were founded on physiognomical, ecological and botanical definitions and influence of human land use. Lantmäteriet has successively developed this system with reference to other works (Sjörs 1948, Ebeling 1978, Hägglund & Lundmark 1981, Elveland 1976, Nordisk Ministerråd 1998) and adopted it to the applied mapping technique. Particular emphasis has been placed on meeting the requirements of the users (Lantmäteriet Norrbottens län and Länsstyrelsen Norrbottens län 1982).

2 Methods

2.1 Aerial CIR photographs – the information source

Ihse (1975, 1978) has described the advantage of using aerial false colour near infrared film (CIR) photographs (slides) for vegetation mapping. Diversity of vegetation appears most evident when including wavelengths of near IR, represented by an extensive range of different red colours in the false colour photographs.

Stereo vision in aerial photographs enables identification of 3D structures and texture (Anon. 1980) e. g. differing a hill (relatively dry) from a hollow (often moist), as well as high trees from low trees, and a hummock mire from an even carpet mire.

The aerial photographs used are from the level of 4600 m corresponding scale 1: 30000, or from 9200 m corresponding 1: 60000. The interpretation instruments normally allow work at 10 times magnification, implying that working scale is approximately 1: 6000 or 1: 3000.

2.2 Field work is necessary for the accuracy of the interpretations

Fundamental for interpretation is that all definitions are calibrated in field. Similarity in photograph to field points of same character is guiding all classification. Continuous calibration is carried out in the vegetation period. Field control points are selected during the interpretation work, to represent both typical classes and common interpretation problems. Calibration of the staff in cooperation is important to reduce differences in result, as well in the field as in interpretation.

2.3 Technical equipment and production

Initially mapping was analogue. Polygons were delineated at plastic sheets accurately attached to CIRslide positives working in a Zeiss Interpretoskop stereo instrument. Handicraft technique was used for producing printing originals. Originals have later been scanned and vectorized to produce digital data bases. From 1993, interpretation of CIR-photographs was done in Zeiss Planicomp 33, directly digitizing vegetation features.

It is possible to map small polygons but the configuration will be very rough at sizes less than 500 m^2. This allows geometrically very detailed mapping, limitations are mainly economical. The issue of scale mainly concerns presentations of maps. If the data collection is geometrically precise, presentation scale could be very different from mapping scale. Though at smaller scales generalization is required and at larger scales there is a risk of extreme magnification of deviations. Expectations for details have increased over time. Maps over the mountain range were generalized for quick production and presentation at 1: 100000. Nine hectares was the minimum mapped unit. For county of Norrbotten the least unit was 3 ha, for Jämtland 1 ha. In south Sweden the minimum unit for a nature type was 0.25 hectare. For lakes and farmland, smaller units were applied, in south as small as 500 m^2.

Currently, interpretation of digital CIR stereo images at computer screens successively replaces Planicomp.

2.4 Covers

The digital vegetation data is arranged in separate covers, or data sets; vegetation polygon cover, forest age class polygon cover, linear objects cover and point objects cover. The whole set is stored as ESRI ArcInfo coverages and available for use as shape files. A unified screen presentation format has been developed for ArcMap.

3 Classification and levels

3.1 Classification system for vegetation polygon cover

Classification system for vegetation must be adopted to the purpose as well as the scale (Ihse 1978). All areas of the landscape are mapped. This is facilitated by the *hierarchical* classification system, in which the landscape observed in the aerial photograph is first divided into major categories, which are further divided by differences in vegetation to the possible level (simplified presentation in Figure 1). As the mapping is completely based on interpre-

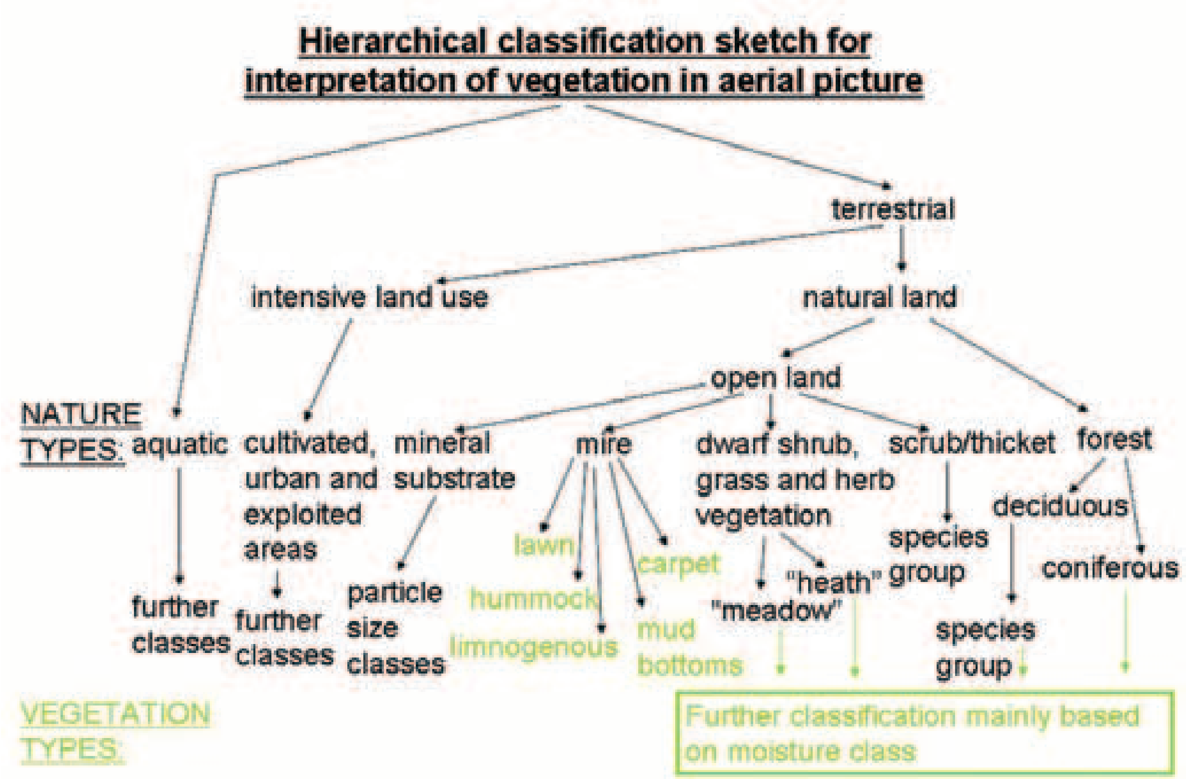

Figure 1: Classification system – black shows general and nature/land use type levels, green shows vegetation type level.

tation of information in the photographs, a rule for the classification is *interpretability in aerial CIR photographs*. Detail level of information presented is designed to meet the *requirements of the users*.

General level – nature types

Aquatic and terrestrial areas are distinguished. Terrestrial areas are further divided into intensive land use (cultivations, urban and exploited areas), forest, scrub/thicket vegetation, open mires, open dwarf shrub – grass – herb vegetation and barren mineral substrate. Dominating characteristics are defining the classification.

Forest is defined as areas with at least 30 % tree canopy cover (Ryberg & Drakenberg 1976, 1978, Löfroth & Rudquist 1996, Nordisk Ministerråd 1998) that normally reach above 3 m when mature. After clear cutting or natural disturbance these areas are still treated as forest, as age class is registered in the separate forest age cover. Aerial photographs from different occasions can be used to detect stability or change. Stable vegetation of open land is divided into grass-herb vegetation (meadows and grass heath), dwarf shrub heath vegetation and finally mires. Mires are characterized as land areas with peat forming vegetation due to high water level, and defined by domination of mire plants according to literature (Nordisk Ministerråd 1998). The peat cover is normally easily interpreted in the photo, but can not define a mire, as peat areas often have been drained and other vegetation e. g. forest established. Drained areas are normally detectable in photographs.

Focus level – vegetation types

Forests are divided into coniferous, dominated by *Pinus silvestris* and *Picea abies*, and deciduous forests, in the north dominated by *Betula* or *Alnus*. In the south also broad leaved, termophile tree species occurs, treated as one vegetation type or at request subdivided according to dominance mainly of *Quercus* and *Fagus*.

In most nature types the basic principle used for classification of vegetation types is the moisture of the soil. This applies to forest, heaths and meadows. Mire vegetation is classified according to major groups of plant societies, as suggested by Sjörs (1948) from the different surface structures; hummock-, lawn-, carpet-, mud bottom-mires, and also limnogenous (alluvial) magnocaricetum fens (Elveland 1976, Nordisk Ministerråd 1998). Water vegetation is distinguished from open water. Barren substrate is classified as outcrop of bedrock or based on grain/particle size, from boulder covered to sand covered areas.

Supplementary information

Supplementary information is provided e. g. for a forest with a mixture of deciduous and coniferous trees, sparse tree or shrub cover on open land, specified water and shore vegetation, structures and trophic status (bog or fen) for mires, and in some cases species characterized varieties of field layer. Further information is provided when required.

Features of subdominant vegetation types (mosaic or deviating area) covering 30 – 50 % of the area in the polygon make up one attribute category.

3.2 Forest age class polygon cover

Most forests in Sweden have undergone clear cutting due to the forest management practice, and are in subsequent phases of development. Classes for mapping are clear-cut areas, young forest, medium aged forest, mature forest and old forest. Supplementary information is recorded about left trees e. g. for seed production, as well as pioneer brush thickets at clear cuttings. This information expires fast, as new areas are clear-cut, and planted trees are growing.

3.3 Natural point objects cover

Natural objects, distinct, but not representing an area suitable for mapping a polygon, are represented by a point with applicable code, e. g. large trees, a spring on an open mire as well as an area of deviating vegetation down to 0.1 hectare (1000 m^2), to small for a polygon (c. 50 classes).

3.4 Natural line objects cover

Natural objects of extended linear shape, distinct but not representing an area suitable for mapping a polygon are represented by a line with applicable code, e. g. a karst crevice at calcareous slabs, a row of trees or a long and narrow fen (21 classes).

3.5 Symbology – cartography

The colour and symbol scheme was developed by Margareta Ihse (1975, 1978) for printed paper maps, and has been adapted by Lantmäteriet to fit extended needs and presentations on computer screens.Basic colours follow nature types and land use groups: Green for forest, brown for heath, yellow for meadow, blue for water and light blue for mire; greyscale with templates for barren substrate, light yellow plus templates for cultivation and white and black templates for urbanized/exploited areas.

Some common symbol principles are used in most groups; brown dotted template for dry, no template for mesic, blue broken lines for moist and blue intact lines for wet vegetation types. Some classes, e g mires, follow separate principles.

Supplementary information is mainly represented by suitable dotted templates with selected symbols, e. g. round rings for deciduous trees. Forest age class cover presents clear-cuts and young reforested areas with grey, diagonal linear templates of different width, and old forests with undulating template. Point and line objects are represented by suitable symbols and colours.

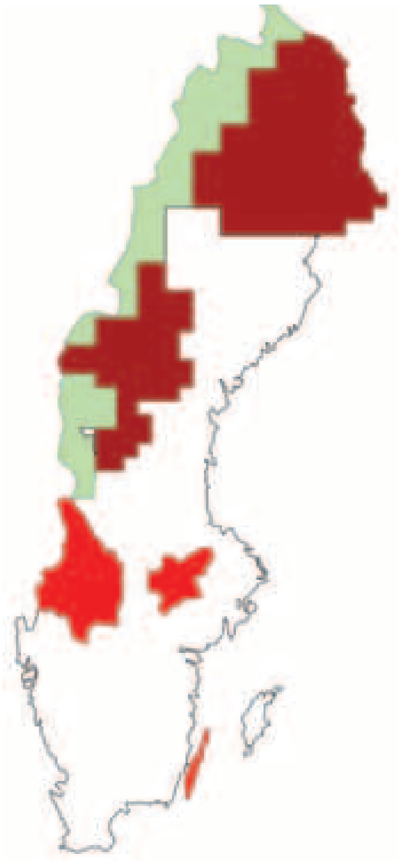

Figure 2: Areas in Sweden where vegetation data is available at Lantmäteriet. Light green: Alpine vegetation data, aerial photo height 9200 m Brown: Vegetation data, aerial photo height 9200 m Red: Vegetation data, aerial photo height 4600 m

3.6 Mapped areas

Geographic vegetation data administered by Lantmäteriet covers 47 % of Sweden (Andersson 2008) Figure 2. This includes alpine vegetation mapping performed by University of Stockholm. Steps are now taken to enable continued mapping.

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BIODIVERSITY – MAPPING AND USE OF DATA

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Abstract

The Norwegian Parliament has decided that the management of biological diversity shall be based on knowledge. Several Ministries have cooperated on a Program for Mapping and Monitoring of Biological Diversity within the following topics: nature types, marine nature types and species, threatened species and alien species.

The Directorate for nature management has made a manual for nature type mapping. The manual describes 56 especially valuable nature types, and the aim is to describe these in the areas most exposed for negative pressure. The data is stored in a database where they can be easily found by everyone.

The nature types must be shown in different types of area plans and regulation plans, and the municipalities and other sectors must be instructed to take care of them. We must have distinct laws and regulations to restrict the loss of biological diversity.

1 Introduction

The Norwegian government aims to stop the loss of biodiversity, and our parliament has decided that the management of biological diversity shall be based on knowledge. To get more knowledge about the most valuable areas we have established a program for mapping and monitoring and a Norwegian center for Biodiversity Information. To get a better management of the areas we have been working with coordination of legal means. We have got a new Nature Diversity Act, and the new Planning and Building Act will be important for taking care of biological diversity in area planning. We have also been working with coordination of economical means.

For biodiversity mapping The directorate for nature management have made manuals for mapping of wildlife (DN-håndbok 11), terrestrial nature types (DN-håndbok 13), marine biodiversity (DN-håndbok 19) and freshwater biodiversity (DN-håndbok 15). For mapping of redlisted species the Norwegian red list (2006) is used.

2 Mapping and quality of terrestrial natural habitats data

We have most experience with quality assurance of terrestrial natural habitats data, and our work with these data is described in this chapter. In 1999 the Norwegian Parliament (Report nr.42 to the Storting) decided that all municipalities should map their biological diversity, mainly nature types, and The Directorate for nature management made a manual for terrestrial nature type mapping. The municipalities themselves were responsible for the mapping. They were given some money to do this work, but it was not enough to map the whole area. It was however a good start in many municipalities, which got a good ownership to the data. The data was used and the localities taken care of in local management.

There was however a big difference in data quality, because the municipalities decided for themselves how to do the mapping and who should do it. In 2006 we had an evaluation of the data, which showed that it was necessary to improve data quality. The handbook was revised, and some of the nature types were updated. Most important was however stronger demands to description and limits. The county governors should now be responsible for the nature type mapping in cooperation with the municipalities. More centralized organization and better quality assurance has increased data quality and comparability.

Our handbook for terrestrial natural habitats mapping describes the biomes which are supposed to be most vulnerable for biodiversity. Within seven main biomes we have classified fifty-six biomes and a great number of sub-biomes. The main biomes are: Mire and springs; avalanche flats, rock and scrubland; mountain; cultural landscape; freshwater/marsh; forest; seashore and coast.

Important requirements for the registrations are:

- A three graded schedule for evaluation, where A is high value (very important), B valuable (important) and C local value (local importance)

- Description must be sufficient of proving habitat type and value
- Boundaries should be set on map 1: 5000

3 Use of biodiversity data

The purpose for the mapping is that the data shall be used in area planning in the municipalities and the sectors. Unfortunately experiences shows that in too many cases the data is not used.

The most important premises for data use are:
- The data must have high quality and coverage.
- The data must be available for the users.
- The data must be used in decision-making processes.

3.1 Data coverage for terrestrial nature types

We do not have resources to map all the vulnerable nature type sites in our country. Therefore the aim is to have a good mapping in the areas most exposed to human pressure, and within these areas the data shall have good quality and coverage. The County Governor shall together with the municipalities and the surveyor find out which areas and biomes to be mapped. The County Governor shall also overview the biome data status, and make a description and positioning of the mapped areas which shows which areas are well surveyed, average surveyed, insufficiently surveyed and not surveyed. It is important that the area planners knows where and what is mapped and how good the mapping is. This is not an easy task, and we are working together with the County Governors and the surveyors to find a good method.

4 Data access and usage

4.1 The data has to be available for the users

Important databases for biodiversity are:
- Naturbase The Directorate for Nature Management is responsible for this database, which in addition to terrestrial natural habitats data contains data from marine biodiversity, cultural landscape, wildlife, conserved areas, and outdoor recreation areas.
- Artskart The Norwegian Biodiversity Center is responsible for this web portal which contains accessible information on the occurrence of species
- Vannmiljøbasen The Norwegian Pollution Control Authority and The Directorate for Nature management is responsible for this database which contains data from freshwater biodiversity.

To make the data available for the users, we have to have:
- More functional databases and better visibility solutions
- Better coordinated databases
- Better updating of the data
- Integration of data into computer programs used by municipality and sectors
- User information and training.

4.2 The data has to be used in decision-making processes

When the data is not used, this may be because the quality and the coverage is not good enough, or the databases are not well enough known and not easily enough available for the users. Another reason is that we do not have distinct enough and clearly enough understandable laws and regulations for taking care of the sites most valuable for biological diversity.

The biodiversity data has to be used in different types of area plans and regulation plans, and the municipalities and other sectors must be instructed to take care of the localities. To achieve this we must have distinct laws and regulations for taking care of the most valuable sites. We have got two important new laws: The Planning and Building Act and The Nature Diversity Act. We also have several important sector laws; The Agricultural Act; The Forest Management Act; The Act relating to seawater fisheries; The Act relating to regulations of watercourses; The Road Construction Act; etc.

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Naturbase www.naturbase.no
Vannmiljøbase http: //vannmiljo.dirnat.no/
The Directorate for nature Management www.dirnat.no
The Norwegian Biodiversity Information center www.artsdatabanken.no
Norwegian Pollution Control Authority www.sft.no
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ANALYSIS OF CORINE LAND COVER RESULTS IN ICELAND WITH REGARD TO ELEVATION AND BEDROCK GEOLOGY

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Abstract

Iceland is an elevated country just south of the polar circle, as reflected in its vegetation cover. The lowlands are predominantly vegetated but vegetation cover decreases rapidly with height. Iceland is also characterised by active volcanism that dominates the appearance of vast barren highland areas. It is therefore logical to ask: 1) how much influence does active volcanism in Iceland have on vegetation cover?, and 2) how much of inland deserts result entirely from high latitude and topography? Combining topographic and geological data with the recently implemented CORINE classification results reveals that, in absence of active volcanism, class 332 (Bare rocks) would decrease by 6576 km^2 causing both an increase in class 322 (Moors and heathland) by 4783 km^2 and an increase in class 333 (Sparsely vegetated areas) by 1591 km^2. Consequently, inland deserts of Iceland would reduce by almost 30 % if effects of volcanism were eliminated.

1 Introduction

The first CORINE classification for Iceland, CLC2006 (Figure 1), completed in december 2008 (Árnason & Matthíasson 2008), provides researchers working in the field of land information and GIS with new and valuable data. Such data can be combined with other types of georeferenced databases to produce new and hitherto unattainable results.

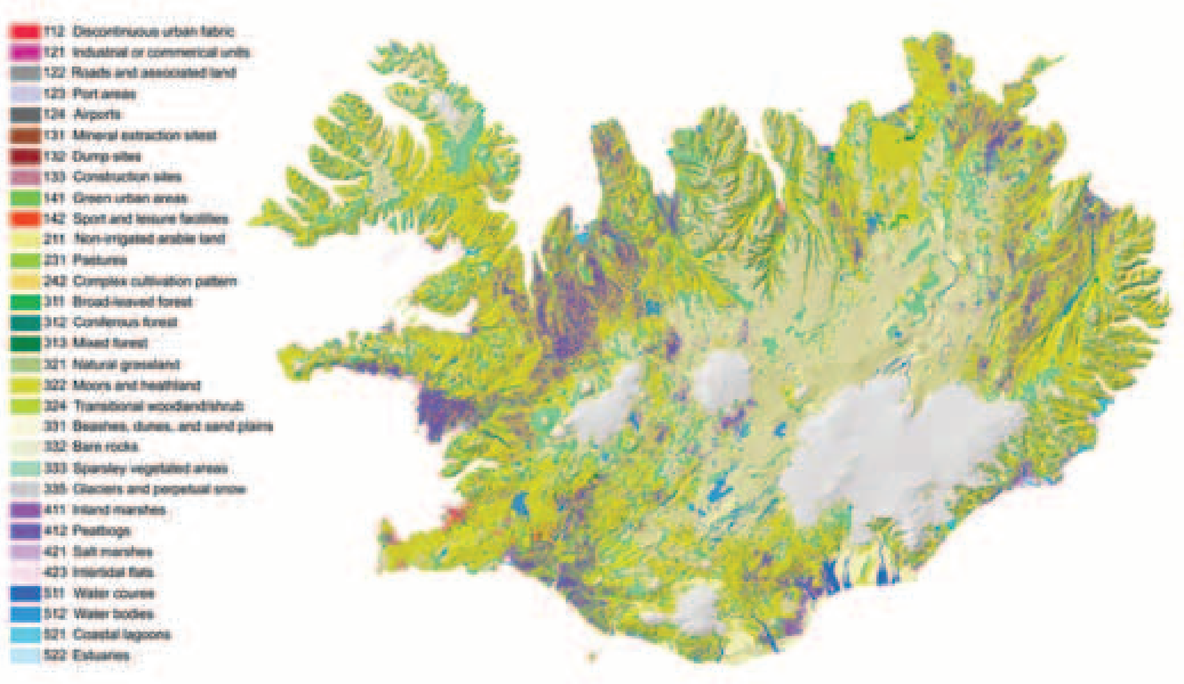

Figure 1: CLC2006 classification results for Iceland. The largest classes are 322 Moors and heathland (35 % of the total area of Iceland), 332 Bare rocks (23 %), 333 Sparsely vegetated areas (13 %) and 335 Glaciers (10.5 %). Peatbogs are displayed in violet and water classes in blue.

Iceland is an elevated country (508 m mean elevation) situated just south of the polar circle, as reflected in its vegetation cover. The lowlands are almost exclusively vegetated but the vegetation cover decreases rapidly with height. The landscapes of Iceland are also characterised by active volcanism in the Neovolcanic zone, that crosses the country from southwest to the northeast (Figure 2) and dominates the appearance of vast barren areas. It is therefore logical to ask: „how much influence does active volcanism in Iceland have on the vegetation cover and how much of the inland deserts results entirely from high latitude and topography?» To explore this the CLC-results have been combined with a digital elevation model (DEM) and a geological map of Iceland within a geographic information system (GIS) and analyzed with regard to topography and the main volcanological formations.

2 Material and methods

CLC2006-results for Iceland are characterised by only four very large classes that completely dominate land cover in the highlands (Figure 1). i.e. 322 Moors and heathland (35 % of the total area of Iceland), 332 Bare rocks (23 %), 333 Sparsely vegetated areas (13 %) and 335 Glaciers (10.5 %). This study aims at mapping the elevation dependence of the vegetation cover within and outside the Neo-volcanic zone (NVZ), respectively. In addition to class 332 (Bare rock, 0–15 % vegetation cover) the CLC-nomenclature contains the nonvegetated class, i.e. 331, Beaches and sand planes (0–15 % vegetation cover), that provisionally needs to be considered in the study (Árnason & Matthíasson 2008).

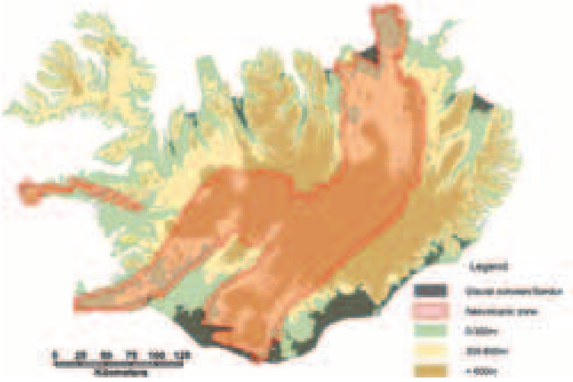

Figure 2: A simplified geological and topographic map of Iceland divided into three elevation intervals; 0–300 m, 300–600 m and above 600 m. Volcanic activity is confined to the Neovolcanic zone (NVZ), that is divided into two branches in S-Iceland. A seperate volcanic area, the Snæfellsnes zone in W-Iceland, has also been active in postglacial time. The NVZ is a subaerial manifestation of the Mid-Atlantic ridge system where active rifting takes place and new volcanic material, ash and lavas, is continuously brougt to the surface. Consequently, the bedrock of Iceland gets gradually older with increasing distance from the NVZ. Hence, rocks become gradually older toward northwest and east. The map also shows the glacial outwash planes that are most prominent close to the large glaciers in S-Iceland (see also Figure 1).

Table 1: Absolute (km^2) and relative (%) areas of the four classes; 322, 331, 332 and 333 in the three elevation intervals inside the NVZ (upper half) and outside the NVZ (lower half). Glaciers and water classes are not considered and have been subtracted from each interval area.

Neovolcanic zone, < 0.8 M yr								
Class	**0-300 m**		**300-600 m**		**> 600 m**		**Total**	**Total**
	km²	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**
322	3570	70,3	3699	34,9	1521	11,5	**8790**	**30,4**
331	56	1,1	511	4,8	714	5,4	**1281**	**4,4**
332	383	7,5	4185	39,5	8958	67,8	**13526**	**46,8**
333	429	8,4	1694	16	1883	14,3	**4006**	**13,9**
total	**4438**	**87,4**	**10089**	**95,3**	**13076**	**99**	**27603**	**95,5**
Interval area	**5078**		**10589**		**13205**		**28872**	**100%**

Bedrock, > 0.8 M yr								
Class	**0-300 m**		**300-600 m**		**> 600 m**		**Total**	**Total**
	km²	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**
322	11960	52,2	11335	55,9	3000	21,7	**26295**	**46,1**
331	337	1,5	43	0,2	43	0,3	**423**	**0,74**
332	655	2,9	2397	11,8	7013	50,8	**10065**	**17,7**
333	1763	7,7	4055	20	3351	24,3	**9169**	**16,1**
total	**14714**	**64,2**	**17830**	**87,9**	**13407**	**97,1**	**45951**	**80,6**
Interval area	**22922**		**20281**		**13816**		**57019**	**100%**

To simplify the analysis the country is divided into three elevation intervals; 0–300 m, 300–600 m and >600 m (Figure 2) (Atlas 2010). Then the absolute and relative (percentage) areas of the three largest CLC-surface classes, i.e. 322, 332 and 333 and class 331 are computed for all three elevation intervals inside and outside the NVZ (Jóhannesson & Sæmundsson 1999) by an overlaying technique using CLC-results and the segmentation of the country as presented in Figure 2. As the results tend to be biased by the uneven distribution of glaciers and water bodies these classes are excluded from all area calculations in the data analysis. The glacial outwash planes represent a surficial formation that actually does neither belong to the NVZ nor the older bedrock outside it and was therefore also excluded from the analysis (Jóhannesson & Sæmundsson 1999).

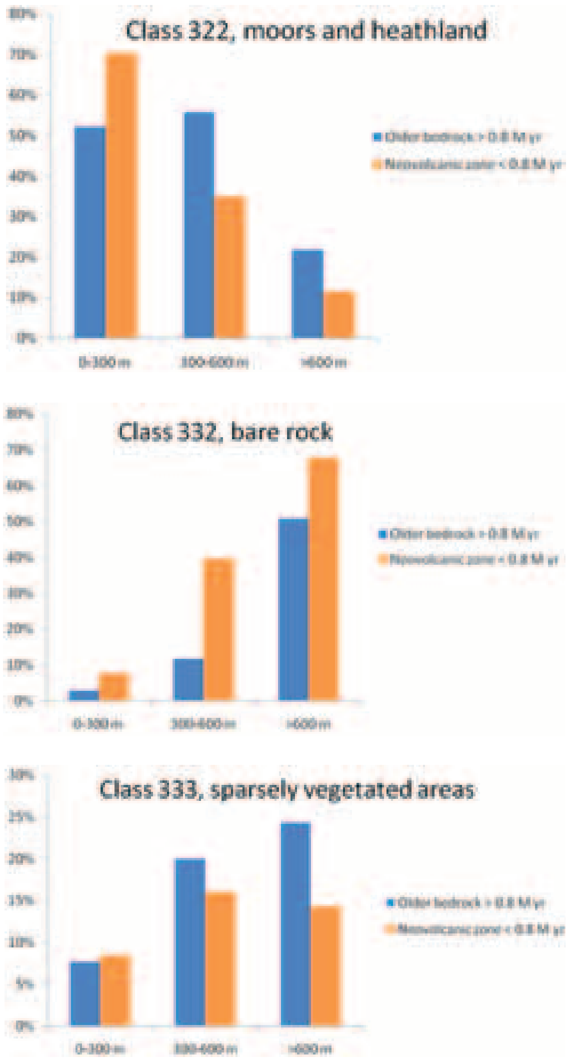

Figure: 3a (top), 3b (middle) and 3c (bottom). Relative coverage of classes 322, 332 and 333 for the three elevation intervals 0 – 300 m, 300 – 600 m and above 600 m.

Assuming that all other environmental influences, e.g. weather and climate, grazing, etc., are more or less independant of geological settings in Iceland and uniform throughout the country, differences in the vegetation cover within and outside the NVZ, respectively, should predominantly result from active volcanism.

3 Results

Table 1 shows results of the data analysis where land cover above 600 m is fully dominated by four main classes that amount to 99.0 % within the NVZ and 97.1 % on the outside, excluding glaciers and water classes. Coverage of the four classes in the 300–600 m elevation zone amounts to 95.3 % inside the NVZ but 87.9 % in the older areas. The lower percentage of the four main classes outside the NVZ is here explained as a result of other vegetation classes, such as grasslands and peatbogs, being more abundant with lower altitudes. Consequently, they constitute quite large areas within this elevation interval in the older sector outside the NVZ.

In the lowest elevation zone (0–300 m) these four classes have a total area cover of 87.4 % inside the NVZ but only 64.2 % on the outside. The explanation is the same as in the previous paragraph: higher vegetation density in the lowlands and the vegetation cover there consist of all possible vegetation classes and not solely 322 and 333 as at high elevation.

These facts are very clearly displayed in figs. 3a., b. and c., where the elevation dependence of classes 322, 332 and 333 is represented. According to table 1 spatial extent of class 331 is limited to the extent that it does not significantly influence the results and can hence be neglected in further considerations. Class 322, Moors and heathland, decreases rapidly with elevation inside the NVZ (Figure 3a). Its smaller percentage area in the lowlands compared with the 300–600 m elevation interval outside the NVZ is, as previously stated, because of considerable coverage of other vegetation classes at lowest altitudes. Class 332, Bare rock, (Figure 3b) behaves in an exactly opposite manner to class 322. Percentage coverage of 332 increases with topographic height both inside and outside the NVZ but is relatively larger inside the NVZ than outside it in all elevation intervals. It is particularly interesting to see the large difference between relative areas of 332 in the 300–600 m height interval (Figure 3b) that confirms the fundamental idea of this study. This difference is smaller for the highest altitudes where vegetation is sparse and it is also smaller at lower elevations where other vegetation classes have higher proportional shares.

Figure 3c shows how the relative coverage of class 333, Sparsely vegetated areas (15–50 % vegetation cover), changes with elevation. Clearly this class behaves in different ways inside and outside the NVZ. This behaviour merely reflects the nature of class 333, i.e. an intermediate class between vegetated and non-vegetated areas. In the older areas outside the NVZ class 333 shows the same tendency as class 332 and, consequently, confirms decreasing vegetation cover with height. Inside the NVZ its coverage decreases from the 300–600 m level to the highest elevation interval, also confirming a decrease in vegetation cover with increasing elevation.

4 Discussion

The results show that spatial extent of CLC classes 322, 332 and 333 change in a very logical manner with increasing elevation (table 1 and figs. 3a, b and c). They also show that the relative coverage of the sparsely and non-vegetated classes 331, 332 and 333 inside and outside the NVZ are very similar in the 0–300 m elevation interval. This means that there is little difference between the vegetation cover inside and outside the NVZ in the lowlands. Above 300 m elevation this difference is, however, quite sigificant. It is therefore interesting to try to introduce a numerical value for this difference and thereby answer the question: „how much influence does active volcanism in Iceland have on the vegetation cover?»

An easy way to demonstrate this is to compute or extrapolate the cover-age for classes 322, 332 and 333 (331 can be neglected due to its small size) above 300 m outside the NVZ to the corresponding elevation intervals inside the NVZ. From this simple computation it can be stated that, in the absence of active volcanism, class 332 would decrease by 6576 km^2 leading to an increase in class 322 of 4783 km^2 and similarly an increase in class 333 by 1591 km^2. This means that the inland deserts of Iceland would be reduced by almost 30 %.

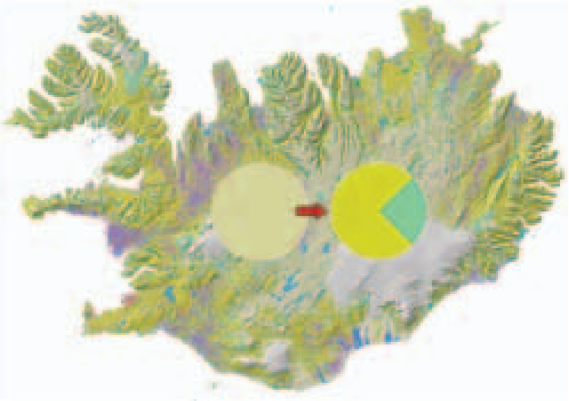

Fig. 4. Volcanism in Iceland is responsible for 6576 km^2 of inland deserts that amounts to 30 % of CLC class, Bare rocks, and 6.4 % of the total area of the country. This corresponds to a circular area of 90 km diameter. Without active volcanism classes 332 and 333 would increase by 4773 km^2 and 1586 km^2, respectively.

This result is displayed in figure 4. An area of 6576 km^2 corresponds to a circular zone of 90 km diameter. In the absence of the NVZ in Iceland some 75 % of the highland desert would be covered by class 322, Moors and heathland, and 25 % would be sparsely vegetated (class 333).

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CLC CLASSES AND THE NORWEGIAN VEGETATION ZONES

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Abstract

The Norwegian CORINE land cover (CLC2000) was completed autumn 2008. The CLC map was generated automatically from a number of dataset using GIS-techniques for map generalisation. The CLC map has a coarse resolution and it is also using a classification system developed in an environment very different from the Nordic. It is therefore interesting to evaluate both content and correctness of CLC. This study shows that there is a good resemblance between the CLC classes and detailed, large scale maps. The diversity in classes on the other hand, is lost due to the CLC classification system.

1 Introduction

The CORINE program was started in 1985, with purpose to establish an information system for reporting and monitoring of the environment (CLC 1994), the CORINE land cover 1990. The CLC database has been updated twice (CLC2000 and CLC2006) since the first edition, and CLC2000 are implemented in most of the EU countries, and most of the Central and Eastern European countries, Norway and Iceland included (EEA 2007).The classification system is equal for the whole Europe and is hierarchic with 3 levels. The CORINE land cover maps are in general manually or semi automatically digitalized of satellite images (IMAGE1990, IMAGE2000 and IMAGE2006) (Bossard et.al. 2000).

Table 1: National datasets used in production of the Norwegian CLC2000.

Dataset		Coverage	Scale
National dataset			
AR5	Land recourses	Below timberline	1:5000
N50	Topographic database	Full coverage	1:50 000
GAB	Real estate register	Full coverage	Point
DEM50	Digital elevation model	Full coverage	50 m
IMAGE2000	Satellite images for CLC production	Full coverage	25 m
Norge-i-bilder	National database of orthorectified air photos	Full coverage	
Interpreted from IMAGE2000			
Arfjell	Mountains and unproductive areas	Above timberline	1:50 000
Young forest	Transitional woodland shrub	Main forest areas	1:100 000
Interpreted from Norge-i-bilder			
Large elements digitalized for CLC2000	Ports Airports Golf courses Industry and construction sites Mineral extraction sites Dump sites Camping ground Sport and leisure facilities Beaches Inland marshes Intertidal flats	Selected sites	

The Norwegian CLC2000 map was generated automatically based on a number of datasets (Table 1). The main input data were national datasets along with ARfjell which was generated within the CLC2000 project. In addition a set of additional dataset were used.

Figure 1: Study area. Location of the vegetation maps in dark green.

Instead of the usual manually digitalizing of the IMAGE2000, the CLC2000 was generalized automatic by using raster techniques and Python scripting. The analyses were done using the ArcGIS Spatial Analyst library. As CLC2000 is a coarse dataset it was sufficient to use 25 m raster for the spatial analysis. A method to join nearby elements by expanding and reducing polygons was very successful.

A final manual inspection and editing was needed to improve the generated data in complicated areas as water ways and industrial areas. In addition some datasets were out of date or missing and needed extra visual control.

The aim of the presented analyses is to evaluate the classification correctness and accuracy of CLC2000, compared with detailed vegetation maps. We also compare the CLC classes to the Norwegian vegetation zones registered in detailed maps and analyse the strength and weaknesses in using highly generalised CLC classes.

Table 2: The vegetation groups and classes used in the Norwegian vegetation maps, and the expected CLC classes to find in this classes.

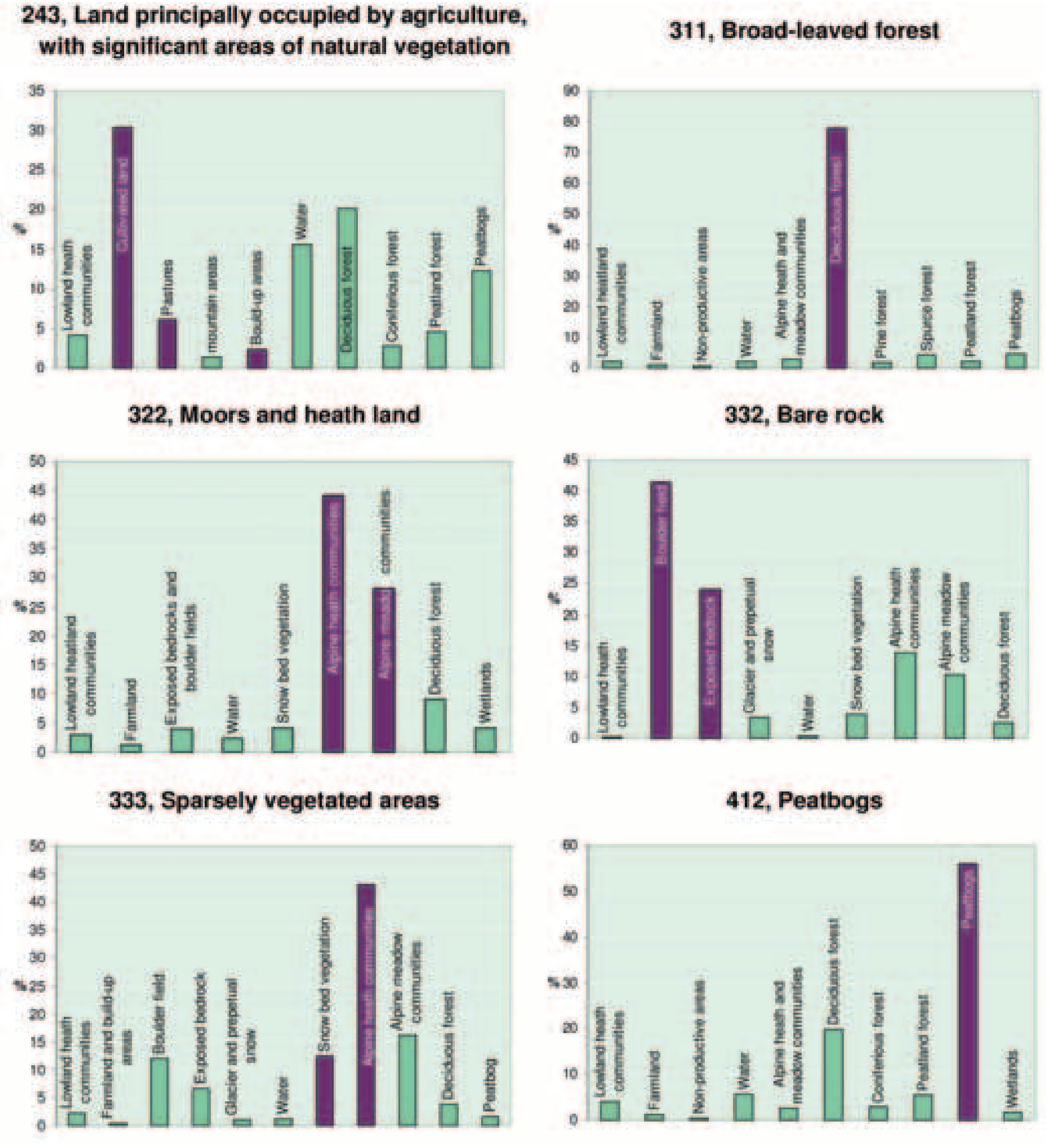
Vegetation groups	Vegetation classes		CLC classes
1 Snow-bed vegetation	1a	Moss snow-bed	333/332
	1b	Sedge and grass snow-bed	333/322/332
	1c	Stone polygon land	333/332
2 Alpine heath communities	2a	Mid-alpine heath	333/332
	2b	Dry grass heath	333
	2c	Lichen heath	333
	2d	Mountain Avens heath	333
	2e	Dwarf shrub heath	333/322
	2f	Alpine callula heath	333
	2g	Alpine damp heath	333
3 Alpine meadow communities	3a	Low herb meadow	322
	3b	Tall forb meadow	322
12 Non-productive areas	12a	Barren land	332
	12b	Boulder field	332
	12c	Exposed bedrock	332

2 Material and Methods

Vegetation maps (scale 1: 20000–50000) from 5 different areas in the northern part of Norway (Figure 1), covering totally 2459 km^2 are used in the overlay with the CLC2000 map. The overlay (GIS intersect operation) was done separately for each area resulting in 5 tables. These tables, along with new features from both CLC2000 and the vegetation maps were joined together in a final table that was used in the analyses. Graphs with the vegetation distribution in percent for 6 different CLC classes, all covering over 100 km^2 were made. This graphs are showing the vegetation profiles (real contents) for the respectively CLC classes.

Based on our experience with satellite interpretation, a table containing the expected CLC classes within each of the vegetation map classes was made. The vegetation map classes are generalized into vegetation groups (according to Table 2).

3 Results and discussion



243, Land principally occupied by agriculture, with significant areas of natural vegetation

311, Broad-leaved forest

322, Moors and heath land

332, Bare rock

333, Sparsely vegetated areas

412, Peatbogs

Figure 2: The vegetation contents (vegetation profile) in different CLC classes. Expected vegetation groups in purple (see table 2). The vegetation distribution in percent of CLC classes covering over 100 km^2 is shown in the graphs.

Below the timberline national datasets exists and are used as main input to the CLC2000. A high correctness of CLC class 311 (broad leave forests) was found and was expected as national datasets covering broad leaved forest exists for most of the country, and are used as input data to the CLC2000. Also class 412 (peat bogs) is generated from national datasets both below and over the timberline, and gives a good result. Class 412 contains 63 % of wetlands when compared to the vegetation maps. As forested wetlands along with small lakes were put in the wetland class in CLC2000 a lower content of pure wetland is to be expected. The class 243 (land principally occupied by agriculture, with significant areas of natural vegetation) does not exist directly in any national datasets. The class is generated by local statistical analysis of scattered agriculture patches that is not included in any of the other agriculture datasets. Class 243 reflects the land use in agricultural areas in North-Norway in a good way. The agricultural areas are small in extent and goes often into a mosaic with forest, semi natural areas and wetlands. The class should have 25–75 % arable land and pasture (Heggem & Strand 2008, CLC 1994). This definition fits well with the result presented in the graph.

Above the timberline CLC2000 mountain vegetation classes were not based on detailed maps, but interpreted in a semi-automatic way through ARfjell and then further generalized into CLC2000. The hit rate of the mountain CLC classes compared to the vegetation classes from the vegetation maps is thus expected to be poorer than below the timberline. The most accurate mountain class is also the most vegetated, class 322 (moors and heath land). The hit rate is 72.0 %. The amount of bare rocks and boulder field in 333 (sparsely vegetated areas) can be related to the mosaic pattern in the mountain areas, and to fact that large minimum polygon size is the generalization process will not be able to reflect such a pattern. The hit rate for 333 was 55.4 %. In class 332 (bare rock) the hit rate was 65.4 %. It is difficult to detect very small or very sparsely vegetated areas in between the bare rocks and boulder field when we use the semi automatic approach based on satellite images. In addition a mixture is to be expected also in this class due to the definition of the CLC2000 dataset.

Based on this analysis it looks like CLC2000 gives a good visualization of the general land cover patterns in Norway both for the mountain- and lowland classes. Because of the generalization process and the small scale with minimum polygon size of 25 ha it is inevitable with a certain amount of mixed vegetation within each class. As several of the heavily generalized CLC classes contain a wide spectre of vegetation classes, vegetation gradients, such as poor to rich vegetation, will not be observed in this small scale, low detailed map. The CLC classes can reflect the Norwegian conditions in a better way, if the different classes are clearly defined and vegetation profiles, such as shown in the graphs, are made.

CLC2000 seems unsuitable for most national statistic analyses and for detailed, local or regional studies and should probably be used on a European scale only. It remains to look at the possibilities for using CLC in combination with other land resource data in order to create area statistics for smaller areas. This will be done in a project at NFLI during 2009–2010. NFLI will also complete the updated CLC2006 by the end of 2009.

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Forest limit changes in southern Norway: ways of giving casual explanations for spatiotemporal changes detected from vegetation maps

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Abstract

Extensive landscape and vegetation changes are apparent within southern Norway, specifically the expansion of forests into new areas and to higher altitudes. Two main processes are believed to cause these changes: regrowth after abandoned human utilisation and recent climate changes. The purpose of this article is to elucidate ways of separating the effects of these two processes on spatiotemporal changes in the upper forest limits using examples from southern Norway. Examples from two spatial scales are implemented, a vegetation map study of a mountain region in south-east Norway and a national map-based study of south Norway. The findings show that multiple methods are necessary to understand the forest limit changes and that the research focus should be on the separation of potential drivers, specifically climate improvements and land-use changes.

1 Introduction

The forest limits of the Nordic countries have varied greatly in altitude since the end of the last Ice Age more than 11,000 years ago (Aas & Faarlund 1988). This variation has been linked to natural climatic changes, mainly variations in temperature. The last period of climatically explained forest limit rise in Norway occurred in the period between 1930 and 1950, approximately concurrent with forest limits advance in other northern regions (Danby & Hik 2007). Recent centuries with human release of greenhouse gases and the subsequent temperature augmentation are predicted to cause a further upward expansion of boreal forests in the northern hemisphere (Holtmeier & Broll 2005; Harsch et al. 2009).

The causes of global upper forest limits and treeline formations have been much debated, but most scientists agree on the hypothesis of a thermal threshold for forest growth at high elevations and latitudes (Körner 2007). The upper potential climatic forest limit of Norway, dominated by mountain birch (*Betula pubescens* ssp. *tortuosa [czerepanovii]*), has been found to be best correlated with the tritherm, which varies strongly in altitude and geographic range along the Scandinavian mountain chain (Aas & Faarlund 2000). However, several other variables should be accounted for when regional or local forest limits are evaluated, such as precipitation, snow cover, spring desiccation, fires, wind, topography, soil conditions, browsing, and human encroachment.

During the most recent decades, the boreal forests of Norway have expanded into sub- and low-alpine areas, resulting in higher local and regional forest limits (Aas & Faarlund 2000; Bryn 2006). Two main processes are believed to cause these forest limit changes. On the one hand, there is regrowth after abandoned or changed human land-use of outfields. The second main process is recent climate change, often focused on higher temperatures at these latitudes and altitudes.

Recently, a number of studies have attempted to separate the effects of recent climate change from those of regrowth following the abandonment of human encroachment on the upper forest limit expansion in regions of previously extensive human land-use of outfields (see Bryn 2009 for references). The aim of the present paper is to elucidate ways of separating the effects of these two processes on spatiotemporal changes in the upper forest limits using examples from southern Norway.

2 Material and Methods

Two spatial scales were included in the study, a regional study of a mountain and valley area in south-east Norway (Bryn 2008) and a national study of southern Norway (Bryn & Debella-Gilo accepted).

The regional study area comprised a mountain and valley profile located in Venabygd, Ringebu Municipality, Oppland County, south-east Norway (*c.*68°38' N and *c.*5°57' E). A total area of 161.5 km^2 was mapped, the lowest part being 330 m a.s.l. and the highest point 1356 m a.s.l. The national study area comprised south Norway in its entirety, including 16 counties and covering 210,836 km^2. The study area ranges from 64.2°N to 72.3°N and from 2.5°E to 7.5°E, from sea level to 2469 m a.s.l., and forms a narrow belt along the north-west Atlantic coast of the Eurasian continent.

Four datasets were used in the regional study. Firstly, forest height growth measures of Norway spruce (*Picea abies* ssp. *abies*) representing the years 1936–2006 were standardised and the measurement were used to interpret climate responses on forest growth alone. Secondly, climate data from the same period and region were put together as respondent variables for the spruce height growth measures. Thirdly, four vegetation maps were constructed to analyse the effect of regrowth following abandoned human land-use compared to those of recent climate improvements on a landscape scale. Actual vegetation maps from 1959 and 2001 were mapped and interpreted based on fieldwork and aerial photos, while a potential natural vegetation map (PNV) and a climate change scenario (CCS) map were constructed by rule-based modelling. The differences between the two actual vegetation maps (1959 and 2001) and the PNV map were then used to indicate the effects of regrowth after abandoned land-use, whereas the forest height growth and recent climate data were used to analyse the separate effects of recent climate change on forest growth and expansion. Fourthly, fenced areas in the region that have excluded the effects of recent domestic grazing were used as indicator of forest growth potential in deforested sub-alpine areas.

The purpose of the national study was to generalise the findings from the regional study. The potential forest limits of southern Norway were found by interpolating 1308 observations of actual forest limits. A digital elevation model (DEM) was transformed into elevation interval zones of 100 m and combined with the potential forest limits through an overlay analysis to a map showing non-forested areas below the upper potential forest limit. The area categories that did not have potential for forest regeneration, e.g. existing forests, rivers, lakes, cities, boulder fields, glaciers, cultivated areas, and bogs, were then subtracted to give a realistic model of the potential area for forest regeneration.

3 Results

The studies involving separating the two main causes of recent forest limit changes and forest expansion in southern Norway have resulted in the proposal to implement three different study-model concepts that will be closer discussed in section 4.

The regional study of forest limits from south-east Norway had two main limitations. It treated only one study region (no replication) and the effect of present-day domestic grazing on the forest expansion was not fully elucidated. These challenges can be solved by implementing all of the elements from the traditional three-level study design of landscape ecology (Figure 1), with comparative field studies, experimental model-systems and theoretical models.

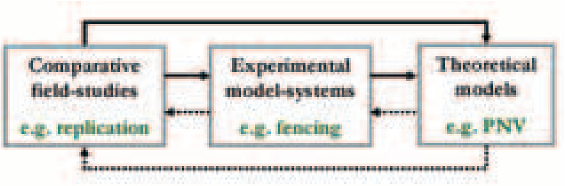

Figure 1: The traditional three-level study design of landscape ecology. Adapted from Ims (1990). See discussion in section 4.

The temporal vegetation transitions from 1959 to 2001 in the regional study did not shed light on small-scale within-vegetation type changes. Such spatiotemporal changes can be monitored by randomised small-plot analyses at other spatial scales within the vegetation map study area (Figure 2). The standardised study on spruce forest height growth and the implementation of local climate data turned out to be very important for the separation of the two main causes of resent forest changes in the region (Bryn 2008).

The modelling of PNV from a vegetation map is both practically and theoretically achievable. However, modelling of the regrowth pattern towards PNV will increase the demand for other types of

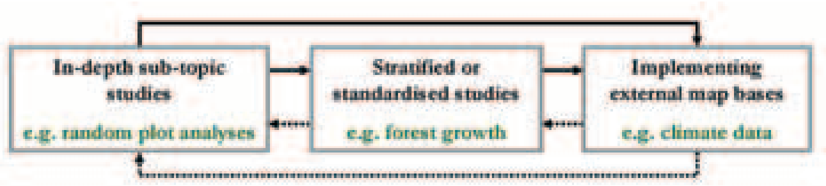

Figure 2: Additional standardised studies at other spatial scales that will increase the ability to separate the effects of different processes on a changing forest limit. See discussion in section 4.

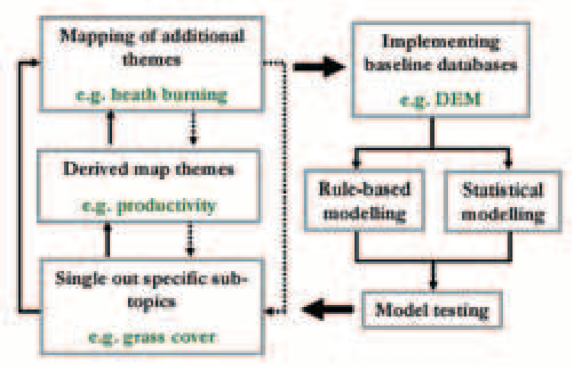

Figure 3: Additional map analyses and map modelling that will generate hypotheses and increase the ability to separate the effects of different processes on a changing forest limit. See discussion in section 4.

data. Such modelling will need additional map layers and map topics (Figure 3). Ideally, such topics and the modelling from them will generate new hypotheses. Finally, the national study of forest limits missed a clear model test, which should be a part of all GIS-models.

4 Discussion

The ability to detect and describe landscape changes from different temporal layers of vegetation maps is well known (Küchler & Zonneveld 1988; Bryn 2011), and a number of landscape monitoring programmes throughout the world register such changes. The ability to explain and separate the different causes of landscape changes, however, varies among the monitoring programmes. The presented results elucidate the need to implement several monitoring or mapping sampling designs if the goal is to separate the effects of different structuring processes causing spatiotemporal landscape changes.

The first study-model concept to be implemented is the traditional three-level study design of landscape ecology (Figure 1), with comparative field studies, experimental model-systems, and theoretical models. Replication of study sites will remove uncertainty related to contingent circumstances of forest expansion (see e.g. Rössler et al. 2008). Fencing will show the effect of domestic grazing on the potential forest limits (see e.g. Austrheim et al. 2008), whereas a model of potential natural vegetation (PNV) will shed light on the expected effect of regrowth after abandoned utilisation (see e.g. Bryn 2008; Hemsing 2010). PNV is an important neutral landscape model that represents natural vegetation which, for example, climate changes can act upon and be modelled from alone (Lapola et al. 2008). The three-level study design will without question influence the sampling design of a monitoring programme. Spatially explicit modelling of, for example, PNV is one aspect that will influence the sampling design (Hemsing 2010). The modelling of PNV maps depends on a monitoring or mapping classification system that registers the ultimate explanatory variables needed for such modelling.

The second study-model concept that proved necessary is to incorporate studies at other spatial scales within the vegetation map study area (Figure 2). In-depth studies of sub-topics, stratified and/or standardised thematic studies as well as the implementation of other spatially explicit map sources will increase the ability to separate the effects of different processes on a changing forest limit. Random small-plot analysis exemplifies a method of obtaining details of changes hidden by the spatial scale of the vegetation map (see e.g. Raynolds et al. 2005). Stratified measurements of forest height growth represents a method of sorting out the effect of climate change alone on forest growth (see e.g. Bryn 2008). Implementing climate scenarios represents a popular way of predicting future forest ranges changes (see e.g. Koca et al. 2006).

The third study-model concept that proved necessary is to work with different map layers and map topics that preferably will generate hypotheses from different types of map modelling (Figure 3). Specific map sub-topics of special interest might be sorted out, derived map topics can be extracted, and also themes other than the vegetation cover can be mapped. Together with other external map bases, specific processes can be spatially explicitly modelled, and thereby shed light on the causes of forest changes. Grass cover is indicative of the extent and intensity of domestic grazing (see e.g. Bryn 2011), productivity reflects the resilience of different vegetation types to human impact (see e.g. Bryn et al. 2010), and heath burning exemplifies the effect of a specific human land-use (see e.g. Bryn et al. 2010). With the inclusion of other baseline maps and spatially explicit explanatory variables, several aspects can be modelled, e.g. the prognosis for forest regeneration.

The conclusion from the studies of forest limit changes and forest expansion in south Norway is clear. The changes can be mapped and quantified with temporal vegetation map layers, but to enable a casual explanation of the monitored changes, a far more advanced study design is needed.

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Methods for landscape monitoring compared

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Abstract

An assessment of the suitability of methods for policy-oriented landscape monitoring in the Netherlands shows that a mix of methods is the most effective approach. Whereas reliable data on new buildings, as well as data on infrastructure and land use, can be gathered from existing GISs, these GISs do not allow monitoring of landscape elements like wooded banks and hedgerows. The best source of information for this kind of data was found to be aerial photographs. Field work is only necessary to check the information gained from such photographs.

1 Introduction

There is currently no systematic monitoring programme on physical changes in the landscape being carried out in the Netherlands. Although the public's appreciation of the landscape is monitored by means of a recently introduced programme of questionnaire surveys (Crommentuijn et al. 2007), it is hard to relate any changes in this appreciation to physical changes in the landscape itself without monitoring such landscape changes. In addition, the lack of systematically gathered data on physical landscape features makes it difficult to describe the current state of the landscape and any emerging trends, and to evaluate the effectiveness of landscape policy, which sets targets for such physical landscape features.

Various aspects of the Dutch landscape have been studied in recent years, to meet the demand for information on changes in the landscape and the effectiveness of policies. Such studies have included research into urbanisation (e.g. Dirkx et al. 2005), into the development of linear plantations (e.g. Koomen et al. 2007) and into changes in the scale of landscapes (e.g. Roos-Klein Lankhorst et al. 2004). The lack of systematically gathered data, however, means that in each new study new methods have been developed and new data sources explored for the required analyses.

The present paper tries to compare the various methods that have been developed in these studies and to evaluate the advantages and disadvantages of each. On the basis of the questions that need to be answered for policy evaluation, it also explores the available options to analyse the current state and development of the landscape as efficiently as possible, despite the present lack of systematic monitoring data.

2 Methodological aspects and data

Given the current developments in the Dutch landscape and the policy efforts that the government is using to control these developments, the demand for data focuses on a number of landscape features:

- Built-up areas (towns, industrial estates), infrastructure and scattered buildings in rural areas.
- Linear plantations (wooded banks, hedgerows, etc.).
- Open landscapes with an unobstructed view of the horizon.
- Parcel shapes.
- Relief.

Since the research is intended to supply information to the Dutch national government, data on these landscape features must be gathered for the Netherlands as a whole. On the other hand, the required level of detail is limited, as the data are to be used in analyses for the whole of the Netherlands, and the results that have to be presented relate to the whole country, to specific provinces or to one of the 11 landscape types that are distinguished in the Netherlands.

The studies underlying the present paper have used various methods and sources to gather data on landscape changes. The sources used can roughly be divided into three categories:

1. National GISs.
2. Aerial photographs.
3. Local situation in the field.

National GISs contain information gathered by third parties, from which landscape information can be quickly extracted with the help of automated analyses, making them the preferred data source for analysing the current state of the landscape and any emerging trends.

One aspect of the use of these GISs that needs to be addressed is the suitability of their data for analyses of the state of the landscape and emerging trends, since the GISs were constructed for other purposes than landscape monitoring. This means that the choices made when interpreting the basic data for the GIS may limit the value of these systems for landscape monitoring. Various researchers have tried to analyse the reliability of the data (e.g. Koomen et al. 2006; De Jong et al. 2009). We have used these studies to evaluate whether these GISs are suitable for analysing the state and developments of the landscape.

The use of aerial photographs or field surveys is only required for those landscape features for which no suitable national GISs are available. In these cases, there is no need to assess the reliability of the source, since in the field the reality is being monitored and photographs simply provide images of this reality. Extracting information from the field situation or from aerial photographs does however involve interpretation or field work, which is time-consuming and raises the question what is the best method to extract the relevant information from the photographs or from the field with a minimum of effort.

One option is the use of automated methods to analyse aerial photographs, using remote sensing techniques. Although early attempts to extract information on linear plantations from satellite images by means of such remote sensing techniques yielded disappointing results (e.g. Dirkx et al. 1989), there are now promising new techniques available which not only evaluate the spectra of each individual pixel, but also use automated pattern recognition. A preliminary explorative study has assessed whether such automated analyses of aerial photographs yield acceptable results (Kramer et al. in prep.).

In addition, the many years of experience gained with ‘manual’ interpretation of aerial photographs ensure that this interpretation is methodologically unproblematic. The use of spot checks to reduce the time investment for manual interpretation of photographs and field surveys has also been investigated.

3 Results

3.1 National databases

The 1: 10,000 topographical map of the Netherlands has been available in digital form since the 1990s; the so-called Top10vector database. Like any topographical map, the database contains spatial information on the topographical features of the landscape, such as buildings and infrastructure, linear plantations, land use and parcel boundaries.

Top10vector is based on aerial photographs and field surveys carried out by the Topographic Service of the Netherlands. The maps are updated every four years. Top10vector is sufficiently detailed and is updated frequently enough to provide a suitable source for analyses of the current state and development of the landscape.

On the other hand, the database also has certain limitations, one of which is the way it is updated. The information is being updated during a four-year cycle. Each year, a quarter of the map sheets are updated. Different sheets therefore represent topographical information from different years. As a result, analyses of changes across the country as a whole show changes over different periods. In other words, an analysis of changes over the 2000–2005 period actually compares the changes over a four-year period around the year 2000 (e.g. 1999–2002) with the situation around the year 2005 (e.g. 2004–2007). In a dynamic landscape like that in the Netherlands, this may lead to significant errors.

A second characteristic limiting the use of Top10vector for landscape monitoring is the fact that the database is being composed for the purpose of preparing topographical maps. Since the topographers aim to produce readable maps, they necessarily have to omit certain objects, even in 1: 10,000 scale map. Any map is inevitably a simplified representation of reality. The choices that the topographers have to make are stipulated in protocols, which show that not everything that would be important for analyses of the state and development of the landscape would necessarily also be regarded as important by the topographers. For instance, linear plantations (rows of trees, hedgerows, etc.) have a lower priority than buildings, roads, etc.

Koomen et al. (2006) compared the information from Top10vector with field observations, and found that whereas Top10vector did provide reliable information on land use, buildings, infrastructure and parcel shapes, as well as on whether a landscape is open or more intimate, the information on linear plantations and relief was not very reliable.

De Jong et al. (2009) compared the data on linear plantations in Top10vector with the information from aerial photographs for a few larger areas, and found that an average of 15 % of the linear plantations that were visible on the photographs were not included in the Top10vector database.

Although relief cannot be analysed accurately with Top10vector either, an alternative national GIS is available for this, the so-called AHN, which contains data on ground level elevations collected by means of airborne laser altimetry. This database offers detailed information on elevation, with a resolution of at least one data point per 16 m2. Koomen et al. (2006) concluded that the AHN was suitable for relief monitoring.

3.2 Aerial photographs

The combination of Top10vector and AHN turns out to be suitable for the analysis of all relevant landscape features except linear plantations. Since no alternative national GIS with accurate data on linear plantations is available, we have looked for other sources of information on these elements. We first examined the suitability of aerial photographs.

A set of digital high-resolution aerial photographs covering the whole of the Netherlands at a resolution of 50 cm has been available since 2003. The photographs were taken in 4 spectra: blue, green, red and near-infrared, allowing vegetation to be clearly visualised. New series of aerial photographs are currently being produced at a rate of once every two years. Since all of the country is photographed within one or two months' time, very little time elapses between the individual images.

This series of aerial photographs represents an excellent source of information for landscape monitoring, and Koomen et al. (2006) therefore concluded that field work is only required to verify the results. On the other hand, the analysis of landscape features does require interpretation of the images. So far, it has proved difficult to extract information about linear plantations from the aerial photographs using remote sensing techniques (Kramer et al. in prep.), as quite a number of elements remain undetected in the analysis. In addition, a great deal of time is required for preprocessing before the automated analysis can be started, due to differences between the photographs in terms of colour and perspective, and due to the effect of shadows on the images. As a result, manual analysis is currently still the most suitable interpretation method. The amount of work involved in this interpretation can be reduced by using random spot checks. Koomen et al. (2006) discussed the statistical aspects of such spot checks in detail for the Dutch situation, and concluded that a sample of approximately 200 spots would allow changes in the length of linear plantations to be assessed with 95 % reliability and a 200 m resolution.

4. Discussion

1. Our comparison of landscape monitoring methods shows that national GISs provide a useful source of data for the analysis of the current state of the Dutch landscape and any emerging trends. The data in these GISs appear sufficiently reliable for the monitoring of nearly all relevant landscape features, although no systematic reliability test has so far been undertaken. Koomen et al. (2006) compared the information from the Top10vector database with field data from the sample of 72 1km2 spots provided by Koomen et al. (2004). However, since this sample was not selected with the intention of testing the reliability of Top10vector, it remains unclear whether the results of their comparison accurately reflect this reliability. The design of the study by De Jong et al. (2009), which compared information on linear plantations from Top10vector with aerial photographs covering large areas, was not sufficiently systematic to allow generalised conclusions on the reliability of Top10vector. A more systematic trial would be required to assess whether Top10vector can be reliably used for this purpose.
2. Another issue that will need to be addressed, besides the reliability of the databases as such, is the required reliability for our national analyses. Although preliminary analyses allow us to conclude that the Top10vector database is

insufficiently reliable as regards linear plantations, it is too early to indicate the level of reliability that is required for these analyses. We will need to examine what level of reliability is required to draw useful conclusions.

3. A decision to use the national GISs would mean that the question whether the relevant analyses can be carried out will depend very much on the availability of these databases. This does not appear to be a problem as regards Top10vector, as the Topographical Map of the Netherlands is produced at the request of the government, regardless of demand. The situation is different, however, for databases like the AHN (elevation): whether updated versions of this database will be made available depends on the demand by its users.
4. Results of attempts to generate information on linear plantations from aerial photographs by means of automated analyses have so far been disappointing. The results might possibly be improved by combining the information from the photographs with AHN elevation data. In this respect, the increased resolution (25 cm) of the photographs made available since 2008 might also offer new opportunities.
5. Although the reliability of the Top10vector data has not yet been fully tested, this database currently seems to be the most suitable data source for analyses of almost all types of information. Supplementary information would only be required for linear plantations and relief. In the process of producing the Topographical Map of the Netherlands, the topographers do observe the linear plantation elements, as they work on the basis of aerial photographs and field checks. It is then up to them, however, to decide whether to include such elements in the map, based on protocols. It might be useful to examine the feasibility of including all plantations in the GIS, with the choice of which ones to include in the map being postponed to the moment when the actual map is produced.

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Mapping resources, livelihood and cultural heritage in coastal Sami fjord landscapes in Finnmark

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Abstract

The paper is based on a cross-disciplinary research project, Fávllis; Traditional knowledge and management of fjords as ecosystems and cultural landscapes. The project includes documentation of traditional ecological knowledge in Coastal Sami fjord areas, as a potential contribution to the knowledgebase for coastal zone management, marine resources and landscape management. By using GIS-mapping technology as a tool for dissemination and presentation of results, ecology, cultural landscape and resource use can be visualised and made relevant for management and planning. In this project, landscape under water, including fishing locations, place names on the sea and narratives connected to the marine cultural landscape has been in focus. Documentation of Sami place names, traditional use of sea areas as well as ecological and topographic characteristics of these areas also contributes to local cultural history and maintenance of Sami identity. The paper presents an example from an ongoing work in Porsanger fjord in Finnmark.

1. Introduction

The present paper is based on a research project focusing on traditional knowledge and ecological change in fjord environments. The concepts of ecosystem and landscape are central to the discourse on environmental and marine resources management and planning. In this project, ecosystem and ecological change primarily refer to the marine ecosystem, in a regonal context. The landscape concept is also primarily used referring to marine landscape or seascape, meaning landscape within a fjord, including landscape under water, as well as islands and coast landscape.

The concept of landscape aspires to broaden the vision and to link ecology and society, in terms of culture and human agency. The EU landscape convention defines landscape as «an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors». The definition is open to the perspective that landscape as we know it is «constructed» through human perception and interaction, that our perception of it is shaped by cultural meaning and language. The EU landscape convention requires a landscape orientation of resource- and ecosystem management, which makes integrating mapping of ecosystem and cultural landscape very relevant as an approach and as a methodological tool.

2. Study area, material and methods

The fjord area we have used as an illustration here is the westside of Porsangerfjord in Finnmark. Coastal Sami communities in this area have been based on mixed economy and harvesting of multiple resources for many generations, the marine resources being the most important sources of livelihood. Sami language is in daily use in these communities. The research project is carried out by NIKU and Centre for Sami Studies, University of Tromsø in collaboration with the Marine Research Institute and local Sami institutions (http: //www.sami.uit.no/favllis/). The mapping component of the project is based on compilation of data from multiple sources. The main data sources are interviews with local fishermen, conducted by participating reseachers or by collaborating institutions. The data on fishing terrirories and spawning sites used for the map example from Porsanger are in part collected from local fishermens' associations for the Fisheries Directorate , while Sami place names are collected by the Coastal Sami Resource Centre (Sjøsamisk kompetansesenter) in Porsanger. The map example shown here represents a work in progress and is not to be considered as a completed product.

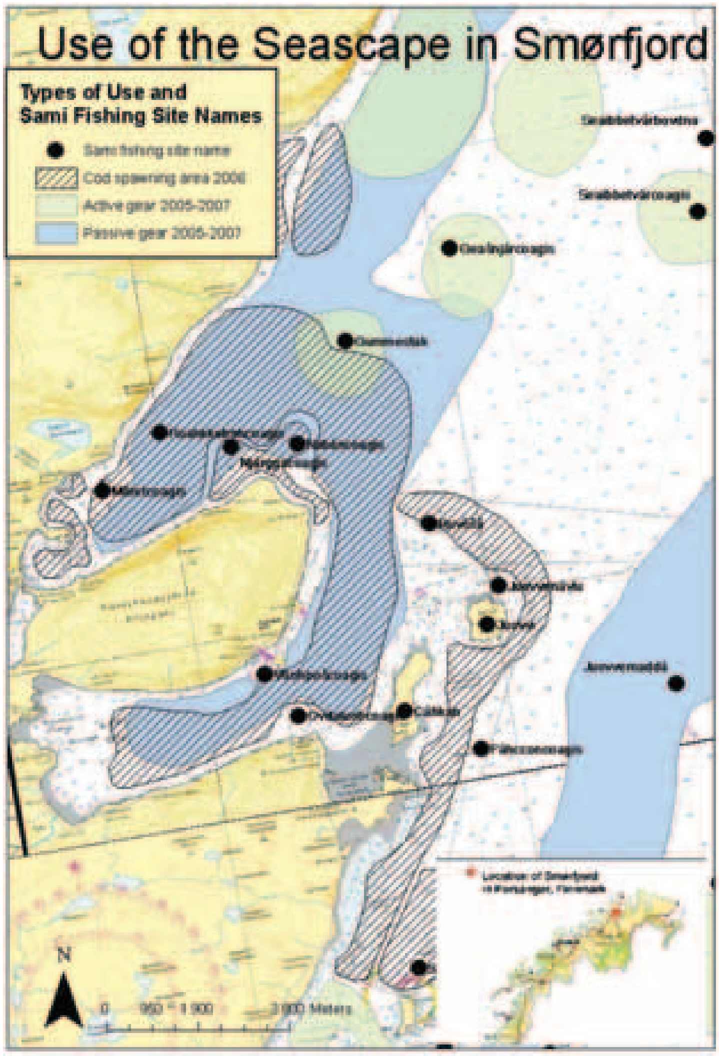

Fig. 1 : Example of a marine landscape map from the westside of the Porsanger fjord, showing harvesting areas where different types of fishing gear is used, spawning areas for cod and Sami place names on the fjord. Based on the official Norwegan sea navigation maps, data from the Norwegian Fisheries Directorate (http: //kart.fiskeridir.no/adaptive/) and fishing site names documented by Coastal Sami Resource Centre, Porsanger (http: //www.mearrasapmi.no/

3. Results

A variety of unpuplished data from academic institutions, local Sami institutions and management institutions, along with some published sources are combined in GIS-based presentations of the marine cultural landscape and Coastal Sami livelihood, in relation to ecological conditions. Map presentation of these data represents an opportunity for multiple uses; coastal zone planning, resource management as well as in teaching of local history, museum exhibitions etc. At the same time, building local knowledge and data collected by the local institutions into the maps, gives us insight into an alternative interpretation and understanding of the landscapes in question. Fig 1. is from the westside of the Porsanger fjord, showing harvesting areas for different types of fishing gear, spawning areas for cod and Sami place names on the fjord. The map presentation highlights the importance of the marine territory as «outfields» of the fjord communities and a vital element of the cultural landscape of these areas. Using data on ecological material presented on static maps, however, involves challenges. The data used by the Fisheries Directorate was published in early 2008, but represents knowledge and use patterns that are already outdated or have changed considerably. The spawning areas for cod shown on the map are today areas with a steeply declining fish stock, and the fields where the passive and active gear are used, are thus changed accordingly as fishers seek out other fishing fields with more fish. The place name material, however, changes at a much slower rate and represents places that carry a long heritage of meaning in the community. The place names represent not only fishing places that were once important, but are also points of reference for talking about the open fjord landscape and for orienting yourself while onboard a boat in relation to the landscape on shore. Many of the place names on the sea are taken from visible mountain tops, land marks, or even houses of the people living on land, thus locating the fishing sites in relation to the whole landscape and also to the community.

The application of different sources for mapping use of the fjords has to be done with changing ecological conditions in mind, making it even more visible how important ecological changes are for the actual use and knowledge about the marine landscape in the local community and in resource management.

4. Discussion

This kind of research also evokes a number of methodological and ethical dilemmas, concerning the relationship between the local, Sami population and the scientists. Can traditional knowledge that is vital to local livelihood be presented openly as maps or in a public database, and how does scientific dissemination affect the content, legitimacy and meaning of traditional knowledge? Local ecological knowledge is knowledge that is open for flexible use and puts ecological changes in relation to the local ecological history of a certain part of the coast or a fishing site. In comparison, fixing use patterns on a map freezes a specific use at a certain time, making the information gathered from local knowledge open for testing by outsiders, new groups of people and for other purposes than it was originally intended. Documentation of traditional resource use is also a highly politicised undertaking, considering the ongoing dispute about indigenous resource-rights and protection of the natural basis of Sami livelihood and cultural practice. This dilemma is dealt with by close collaboration with local Sami institutions, and the data presented here are not considered sensitive in this sense. The methods of finding fish and fishing grounds have changed with new technology, and «secret spots» to the extent they exist under the current conditions, are not revealed on these maps. Also, the details of the collected data are hardly understandable without the cultural «meta-data» following along with the local knowledge used for the maps. However, for the purposes of creating an impression of the density of important sites in the marine landscape, visualisations are useful for both researchers, management and for affirmations of local history, culture and identity. At a larger scale, creating aggregated maps visualizing use patterns and important cultural features of the marine landscape makes analysis of ethnic and/or rights relations possible.

Digital maps are powerful tools, and mapped knowledge appears as more «valid» than oral tradition as a source on resources, traditional use and changes in the landscape/seascapes of the fjords. The question of validity and reliability of local knowledge vs scientific data is also an issue here. In general these areas are not well covered by biological research, but comparison between biology and local ecological knowledge, if possible, is facilitated by research collaboration with the Marine Research Institute, which has recently initiated an ecological study in the Porsanger fjord.

There have been disagreements between biologists and fishermen on certain issues such as the number of seals in the Porsanger fjord, but in general there has been openness between scientists and local fishermen on each others ecological knowledge. As these areas, Porsanger fjord in particular, are inhabited by multiple ethnic groups; Sami, Norwegians and Kvens, there can be up to three different place names for the same location as all three groups have left their inscription on the landscape.

By integrating mapping of place names and narratives with ecological characteristics, underwater topography, as well as traditional and current use of resources and territories by different ethnic communities, the interconnections between cultural and ecological elements of the landscape are visualised and made relevant for landscape oriented planning and management.

Acknowledgements

Thanks to Coastal Sami Resource Centre for the contribution of data on Sami place names.

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Large scale mapping of the Sestroretskoe mire, NW Russia

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Abstract

This paper is concerned with some methodic aspects of vegetation mapping, particularly large scale mapping of mire vegetation. A case study, Sestroretskoe mire is a new prospective nature reserve near St. Petersburg. Field observations were done in the summers of 2005–2006. Vegetation relevés located with GPS-coordinates along the study transects were used for aerial photo interpretation and mapping. An explanatory text to a large-scale vegetation map is presented.

1 Introduction

A case study, the Sestroretskoe mire (1279 ha), situated 30 km to the northwest from St. Petersburg, is a well-preserved raised bog close to the Gulf of Finland. Co-ordinates of the bog centre are 60°06' N 30°01' E. The total area of peatland is 1279 ha. It consists of two clearly distinguished parts: the northeastern one is a typical raised bog with pool and hummock-hollows complexes; the southwestern part is a cotton grass bog. Its surface is very flat and plateau-like. M. Succow & H. Joosten (2001) identified the Sestroretskoe mire as a plateau-bog.

The Sestroretskoe mire has developed in the Littorina sea lagoon. Two parallel chains of sandy dunes extend through the mire from the north-west to the south-east. The average depth of peat deposits is 3–4 m. At the beginning of the XVIII century a water reservoir was made by building a dam on the river Sestra. Nowadays it remains as an artificial lake called Razliv.

As a whole, the Sestroretskoe mire can be identified as a typical oligotrophic mire massif that includes mesotrophic and mesoeutrophic mires in the margins. The western part of the mire is the richest one in nutrients: the Sestra river flows through the mire. The lagg has developed in the northeastern margins. The Sestroretskoe mire has got both the features of the European sub oceanic sphagnum raised bogs and those of the North-West- European ones (particularly the Russian west type) according to Юрковская (1992).

2 Materials and Methods

The vegetation map of the Sestroretskoe bog was made with a help of the spectra zonal aerial photographs, topographic maps in the scale of 1: 25 000. The archive data as well as the old topographic maps were studied to reconstruct the landscape changes during the last three centuries.

Field observations were done in the summers of 2005 and 2006. The original data such as vegetation relevés, located with the GPS-coordinates along the field profiles, were the basis for aerial photo and space image interpretation and mapping. The vegetation map can be considered as a model of a plant cover because vegetation is generalized according to a certain scale. The classification results are usually used in map's legends (Sochava 1979). The mire vegetation in our case was classified according to the Braun-Blanquet floristic approach.

The distinguished communities were verified with the literary data previously published (Богдановская-Гиенэф 1928; Боч & Смагин 1992; Osvald 1923; 1925; Warén 1926; Påhlsson 1994). A large-scale vegetation map, an explanatory text as well as a typological scheme of mire vegetation were prepared. Mapping approaches to complex mire vegetation developed by Юрковская (1992) were used. The correspondence of vegetation classification units (associations) and mapping units according to the traditions of the Russian vegetation mapping school were studied.

3 Results

The large scale vegetation map of the Sestroretskoe mire in the scale of 1: 25 000 was made. Rare plant communities as well as common ones were mapped. An explanatory text was compiled on the basis of field observations and vegetation relevés.

The data were separated into three large groups by their nutrient status: oligotrophic, mesotrophic, mesoeutrophic and eutrophic communities (Figure 1). pH data support eutrophic, mesoeutrophic, mesotrophic, oligotrophic and ombro-oligotrophic levels (Rehell & Heikkilä 2009). These groups became the main divisions of the map's legend. Some subdivisions are recognized according to physiognomic features of plant communities, such as the presence or absence of trees and density.

The following communities represent oligotrophic vegetation. Pine dwarf shrub moss communities occur on very low and paludified sandy dunes. *Ledum palustre* and *Chamaedaphne calyculata* prevail among dwarf shrubs. The moss cover includes *Sphagnum angustifolium* and green mosses *Pleurozium schreberi* and *Dicranum polysetum.* Dwarf birch *Betula nana,* a relict of glacial period, was recorded from one of the similar sites.

Pine bog vegetation appears on raised surfaces with a thick peat. Bog communities with sparse Scots pine are widely spread. Bog myrtle *Chamaedaphne calyculata* and heath *Calluna vulgaris* are dominant plants commonly. Heath-sphagnum communities are typical of the southern boreal mires close to the Atlantic cost.

Communities Empetrum nigrum-Sphagnum fuscum, which are common for the northern areas, can be found on the mires of the Karelian Isthmus and the Sestroretskoe mire as well.

The mapping process is more complicated in case of diverse and heterogeneous vegetation. A number of mapping units represent complex vegetation. Hummock-hollow complexes occupy large areas in the northeast. The bog pool complex has a limited distribution there. *Sphagnum fuscum* predominates on bog hummocks. Both *Calluna vulgaris* and *Chamaedaphne calyculata* are common. Bog myrtle is on the western border of its distribution. *Sphagnum rubellum* as well as *S. tenellum* can be found on low hummocks. *Scheuchzeria palustris* grows in bog hollows. *Rhynchospora alba* prefers regressive hollow complexes with liver mosses and *Sphagnum cuspidatum.*

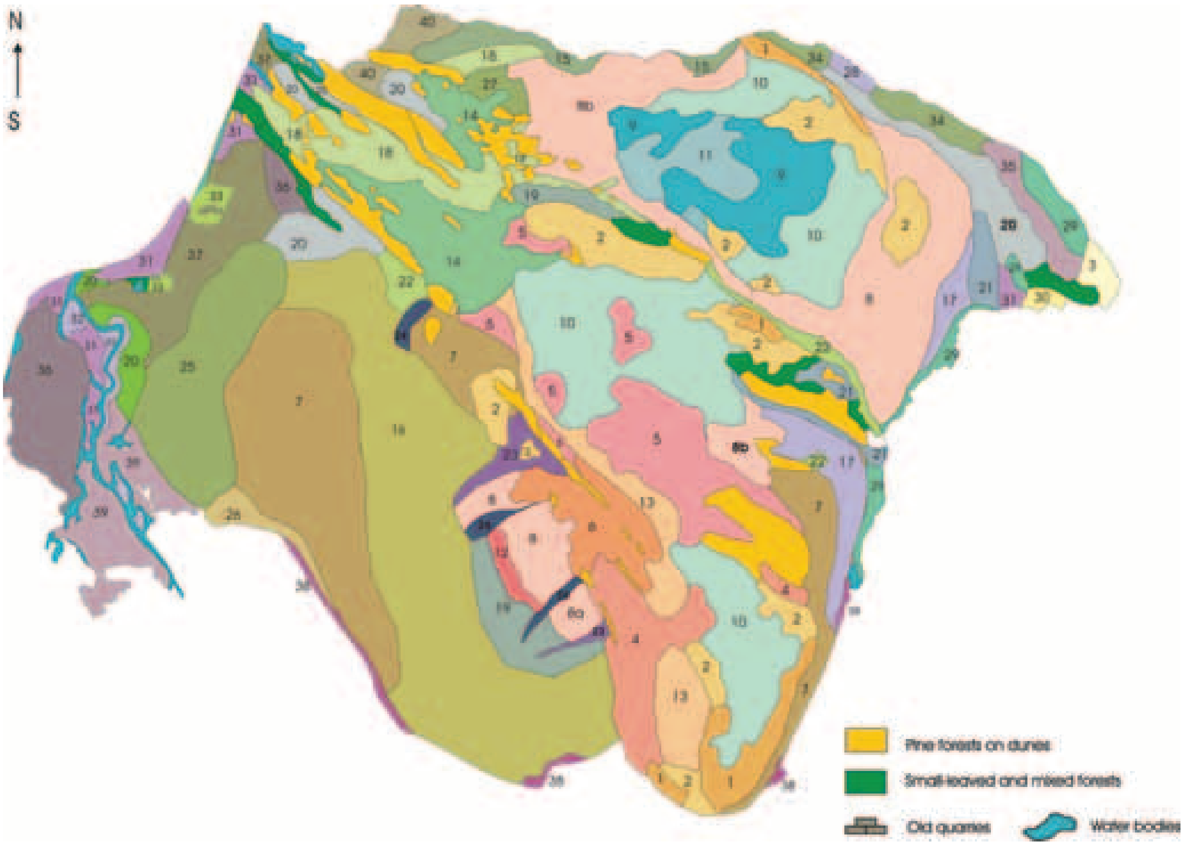

Figure 1: Vegetation map of Sestroretskoe mire. See appendix for detailed map legend.

Some other complex vegetation types are shown on the map also. For example, Sphagnum papillosum carpets with scattered low hummocks are widely spread. *Empetrum nigrum* and *Sphagnum fuscum* grow on these hummocks.

Cotton grass bog communities cover some large areas to the south of the dune ridges. Sedges *Carex rostrata* and *Carex lasiocarpa* are sporadically occur in the plant cover.

Overlogged lawns with small sedges and sphagnum mosses have limited distribution. They are shown on the map with very small and narrow contours.

Mesotrophic mires occur in the margin parts of mire system. They are birch sedge (*Betula pubescens, Carex rostrata, C. limosa*) and forbs sphagnum (*Menyanthes trifoliata*, *Sphagnum fallax, S. flexuosum*) mires.

An interesting mire vegetation complex was found in the northeastern part of the mire. Sedge-forbs hollows (*Carex limosa, Menyanthes trifoliata*) and pools with *Utricularia intermedia* and *Nympaea candida* were there.

Mesoeutrophic and eutrophic mires are rather diverse. They can be found along the mainland. Sedge mires with sparse willows (*Salix cinerea*) alternate with common reed sphagnum mires having small black alders and birches. Vegetation continuity in the lagg is shown by the topo-ecologic set of communities.

The westernmost part of the mire is separated from the main bog by the river Sestra. In general, it is called sedge-forbs-sphagnum mire (*Carex rostrata, Comarum palustre, Sphagnum flexuosum, S. obtusum*). Willow sedge sphagnum mires (*Salix cinerea, S. phylicifolia*, *S. triandra*) spread along the river Sestra. *Carex acuta*, *Sphagnum riparium* and *S. squarrosum* grow along the river. Eutrophic communities with the predominance of *Equisetum fluviatile* occur near the Sestroretsky Razliv Lake.

The area studied has both historical and natural value. It is intended in future to make the Sestroretskoe bog a complex nature reserve, aiming to control the increasing anthropogenic pressure on bog ecosystems and to improve the ecological situation in the artificial lake. What is the most important is to protect biodiversity and unique bog habitats in the vicinity of St. Petersburg. Detailed inventories of local landscapes, flora and fauna will be published in a collective monograph in a series of books on nature conservation areas of St. Petersburg and the Leningrad region.

4 Discussion

To sum it up, the Sestroretskoe mire has got the main features of its geographical and hydrological types partly disturbed by anthropogenic factors.

From the point of view of methods a legend to the vegetation map is based on certain vegetation classification (Сочава 1979). When making a legend we classify plant communities according to their floristic composition and structure. But, the tasks of vegetation mapping are different from those classification goals; a map supposes to show general regularities and spatial distribution of plant communities. It is also necessary to show the specific floristic and phytocoenotic features of vegetation (Мазинг 1962) on the map. At the same time they should not overshadow a geographic type of mire (Галкина 1962).

Acknowledgements

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Appendix:
Legend to the vegetation map of Sestroretskoe mire

Mire vegetation
OMBRO-OLIGOTROPHIC AND OLIGOTROPHIC VEGETATION

Pine tree communities (Pinus sylvestris f. uliginosa, f. litwinowii)

1. Pine dwarf shrub sphagnum (*Pinus sylvestris, Chamaedaphne calyculata, Ledum palustre, Sphagnum angustifolium*) [h=4—6 m][1].
2. Pine dwarf shrub sphagnum (*Pinus sylvestris, Calluna vulgaris, Chamaedaphne calyculata, Empetrum nigrum, Rubus chamaemorus, Sphagnum angustifolium, S. magellanicum*); [h=3 m].
3. Pine-common reed-sphagnum (*Pinus sylvestris, Phragmites australis, Sphagnum flexuosum, S. fallax*).

Communities with sparse pine trees (Pinus sylvestris f. litwinowii)

4. Bog myrtle-sphagnum (*Chamaedaphne calyculata, Sphagnum magellanicum, S. angustifolium*) [h=0.5—2 m].
5. Heath-sphagnum, sometimes with bog myrtle (*Calluna vulgaris, Sphagnum magellanicum, Chamaedaphne calyculata*) [h=3 m].
6. Crowberry-sphagnum (*Empetrum nigrum, Sphagnum fucum*) [h=1.0—2.5 m].

Open communities

7. Cotton grass-sphagnum, sometimes with dwarf shrubs (*Eriophorum vaginatum, Sphagnum magellanicum, S. angustifolium*, *Chamaedaphne calyculata,Oxycoccus palustris*).
8. Cotton grass-sphagnum (*Eriophorum vaginatum, Sphagnum*):
    8а. *Sphagnum balticum*.
    8б. *Sphagnum fallax, S. papillosum*.

Complex communities
Ridge-pool complexes with regressive hollows

9. Heath-sphagnum with pine trees (*Calluna vulgaris, Sphagnum fuscum, Pinus sylvestris*) [h=1—1.5 m] on ridges, Rannoch-rush-sphagnum (*Scheuchzeria palustris, Sphagnum cuspidatum*) in hollows, sometimes with *Carex rostrata,* and white beak sedge-liver mosses (*Rhynchospora alba, Cladopodiella fluitans*) in pools.

Hummock-hollow

10. Pine-dwarf shrub-communities (*Pinus sylvestris, Calluna vulgaris, Chamaedaphne calyculata, Sphagnum fuscum*) [h=2 m] on hummocks, cotton grass-sphagnum (*Eriophorum vaginatum, Sphagnum balticum*) in hollows;
11. Heath-sphagnum (*Calluna vulgaris, Sphagnum fuscum*) on hummocks, cotton grass-sphagnum (*Eriophorum vaginatum, Sphagnum rubellum*, *S. tenellum*) in hollows.

Hummock-hollow-carpet

12. Crowberry-sphagnum (*Empetrum nigrum, Sphagnum fuscum*) on hummocks, small sedge-sphagnum (*Carex limosa, Sphagnum majus*) in hollows, Rannoch-rush-sphagnum (*Scheuchzeria palustris, Sphagnum balticum, S. papillosum*) in carpets.

Hummock-carpet

13. Dwarf shrub-sphagnum (*Calluna vulgaris, Empetrum nigrum, Chamaedaphne calyculata, Sphagnum magellanicum, S. fuscum*) on hummocks, cotton grass-sphagnum (*Eriophorum vaginatum, Sphagnum angustifolium*) in carpets.
14. Crowberry-sphagnum (*Empetrum nigrum, Sphagnum fuscum*) on hummocks, cotton grass-sphagnum (*Eriophorum vaginatum, Sphagnum papillosum*) in carpets.

MESOOLIGOTROPHIC AND MESOTROPHIC COMMUNITIES
Communities with sparse birch trees

15. Birch-sedge-bog bean-sphagnum (*Betula pubescens, Menyanthes trifoliata, Carex lasiocarpa, Sphagnum fallax*).

Open sedge-sphagnum mires

16. Sedge-cotton grass-sphagnum (*Carex rostrata, C. lasiocarpa, Eriophorum vaginatum, Sphagnum fallax*).
17. Sedge-sphagnum (*Carex rostrata, C. limosa, Sphagnum fallax*).
18. Sedge-sphagnum (*Carex lasiocarpa, Sphagnum fallax, S. papillosum*).
19. Sedge-sphagnum (*Carex rostrata, Sphagnum papillosum*).
20. Sedge-bog bean-sphagnum (*Carex rostrata, C. lasiocarpa, C. limosa, Menyanthes trifoliata, Sphagnum fallax, S. flexuosum*).
21. Bog bean-sedge-common reed-sphagnum (*Menyanthes trifoliata, Carex lasiocarpa, Phragmites australis, Sphagnum fallax*).
22. Sedge-sphagnum (*Carex limosa, Sphagnum papillosum, S. majus*).
23. White beak sedge -sphagnum (*Rhynchospora alba, Sphagnum papillosum, S. majus, S. fallax*).
24. Rannoch-rush-sedge-sphagnum (*Scheuchzeria palustris, Carex rostrata, Sphagnum majus*).

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[1] Tree height

complex communities

Hummock-carpet

25. Birch-bog myrtle-sphagnum (*Betula pubescens, Chamaedaphne calyculata, Sphagnum magellanicum*) hummocks, sedge-bog myrtle-sphagnum (*Chamaedaphne calyculata, Carex rostrata, Sphagnum angustifolium*) carpet.
26. Bog myrtle-sphagnum (*Chamaedaphne calyculata, Sphagnum magellanicum*) on hummocks, sedge-sphagnum (*Carex limosa, C. rostrata, Sphagnum fallax*) in carpets.

Carpet-hollow

27. Sedge-Rannoch-rush-sphagnum (*Scheuchzeria palustris, Carex lasiocarpa, Sphagnum papillosum*) in carpets, sedge (*Carex limosa*) in hollows.

MESOEUTROPHIC AND EUTROPHIC COMMUNITIES

Communities with Black Alder trees

28. Black alder-willow-sedge (*Alnus glutinosa, Salix cinerea, Carex vesicaria*).
29. Common reed-sedge-sphagnum (*Carex lasiocarpa, Phragmites australis, Sphagnum squarrosum, S. angustifolium, S. fallax*) with sparse black alder (*Alnus glutinosa*) and birch (*Betula pubescens*) trees.

Communities with Willow trees and shrubs

30. Willow-tall forbs (*Salix cinerea, S. phylicifolia, Calamagrostis canescens, Filipendula denudata, Thyselium palustre, Iris pseudacorus*).
31. Willow-forbs-sedge-sphagnum (*Salix cinerea, S. phylicifolia, Carex acuta, Comarum paluste, Sphagnum riparium, S. squarrosum*).
32. Willow-Horsetail (*Salix triandra, S. cinerea, Equisetum fluviatile*).
33. Broad-leaf cattail-forbs-sphagnum (*Comarum palustre, Thyselium palustre, Calamagrostis neglecta, Typha latifolia, Sphagnum riparium*) with willow shrubs (*Salix cinerea*).
34. Yellow iris-sedge (*Carex vesicaria, Iris pseudacorus*) with sparse willow shrubs (*Salix cinerea*).

Open forbs and forbs-sphagnum mires

35. Sedge-bog bean (*Carex lasiocarpa*, *C. limosa, Menyanthes trifoliata, Sphagnum platyphyllum*) with Bladderwort (*Utricularia intermedia*) and bog lily (*Nymphaea candida*), sometimes, common reed-sedge-sphagnum (*Carex lasiocarpa, C. limosa, C. chordorrhiza, Phragmites australis, Sphagnum obtusum, S. flexuosum*).
36. Sedge-forbs-sphagnum (*Carex rostrata, Menyanthes trifoliata, Comarum palustre, Calamagrostis neglecta, Sphagnum flexuosum, S. obtusum*).
37. Broad-leaf cattail-purple marshlocks sphagnum (*Typha latifolia, Comarum palustre, Sphagnum squarrosum, S. flexuosum*).
38. Common reed-forbs-sphagnum (*Phragmites australis, Comarum palustre, Thyselium palustre, Sphagnum riparium, S. papillosum*).
39. Forbs (*Equisetum fluviatile, Carex acuta, Calamagrostis neglecta*).

Topo-ecologic set of communities

40. Willow-forbs-sedge-moss with Broad-leaf cattail (*Salix phylicifolia*, *Carex rostrata, C. limosa, C. cinerea, Comarum palustre, Thyselium palustre, Typha latifolia, Calliergon cordifolium, Brium pseudotriquetrum, Sphagnum obtusum*) — purple marshlocks-sphagnum (*Carex rostrata, Comarum palustre, Sphagnum fallax*, *S. riparium*).

Mapping and density analyses of drainage ditches in Iceland

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Abstract

The network of wetland drainage ditches in Iceland was digitized using SPOT 5 satellite images. Total length of ditches mapped is 29 700 km. The aerial density of the ditch network was analyzed using the Kernel density function of ArcGis. The function calculates density of linear objects (ditches) per square kilometer. The total size of area with ditch density greater than 0.1 km/km^2, is 5837 km^2.

1 Background

The landscape of the lowlands of Iceland is in large areas characterised by drainage ditches. The purpose of this extensive drainage was, for most part, to make wetland areas more suitable for cultivation and grazing.

When new heavy machinery came in to use in Iceland early in the 1940's, extensive drainage of wetlands was made possible. It was believed by most people, that drainage was important for further improvements in agriculture and hence a broad network of ditches was excavated. Beside the agricultural draining, ditches were also excavated as part of road construction (Geirson 1998) and some ditches were dug for other purpose, e.g. to supplant fences or to serve as effluent from draining systems.

Total length of ditches is not known and no maps have been available of the drainage system. This exploitation of wetlands for agricultural use was governmentally subsidized during the period 1942 to 1987. Since then only maintenance of existing drainage has been supported in that manner (Geirson 1998). According to the documentation of the Farmers Association of Iceland, there were 32 700 km of ditches excavated from 1942 to 1993 (Óskarsson 1998). Some new draining has been carried out since 1993, but no information is available on the extent of this recent draining. A map of Icelandic water network, which was done by Loftmyndir ehf. (2009) indicates that the ditch network in Iceland is approx 32 500 km in length; that map is not yet available for research to the Agricultural University of Iceland.

It is difficult to estimate the extent of the area affected by a given ditch. Some ditches can affect large areas, like those that are dug in slopes and stop water flow which under normal conditions would run throughout the soil downhill. Other ditches apparently have hardly any effects on the water level and the land is still wet, for example where the land is too flat for water to adequately drain through the network of ditches. The lifetime of ditches is also variable. Some ditches over time are filled up with sediments or collapse so their drainage efficiency decreases. It is also difficult to identify areas which are sufficiently drained and those which are not, because a ditch can lower the water level but not sufficiently drain the area (Geirsson 1975).

No reliable estimate is available as to the overall size of the drained area for the entire country. Some estimations have been carried out and there is a large difference in the outcome depending on what premises were used (Óskarsson 1998). Óttar Geirson (1975) has approximated that each ditch drains a 50 m wide area. If that number is used, 20 km of ditches are needed to drain 1 km^2. Using this approximation then 32 700 km of ditches have drained an area of 1620 km^2. Óskarsson (1998) surveyed draining and the remaining wetlands in the Borgarfjörður district. As part of that project, he analysed how many km of ditches were needed to drain the wetlands in one municipal, Reykholtsdalur. The conclusion was that 7.3 km of ditches were needed to drain1 km^2. Based on that results he estimated that these 32 700 km of ditches had drained area of 4 500 km^2. Magnússon and Friðriksson (1989) assert that the influences of drainage ditches extend far beyond the 25 m on each side. In addition, the results of a remote sensing project indicate that changes in vegetation composition can extend as far as 200 m distant from the draining ditches (Gísladóttir et al. 2008).

In recent decades, considerable research has been done on wetlands and drained areas in Iceland, but there has been a lack of geographical information on the extent and the efficacy of draining and the size of remaining wetlands. The main purpose of this ditch mapping and the density analyses is to improve our knowledge and understanding and to make it easier to interpret research results and make all estimates more accurate.

2 Methods

The entire network of ditches in Iceland was digitized on basis of SPOT 5 satellite images, which were taken during the years 2002–2007. These SPOT images can be enlarged up to scale about 1: 5 000. In some areas the mapping was visually compared with aerial photographs because ditches are in some cases better distinguishable in such images.

The aerial density of ditches was analyzed in ArcGis using the Kernel density function. The function calculates density of linear objects (ditches) on square km. The output is a raster image (10x10 m) where each cell has a value depending on distance from ditches (Figure 1). (Kernel function for lines is adapted from the quadratic Kernel function for point densities as described by Silverman (1986) (ArcGis 9.3, desktop help, 2008).

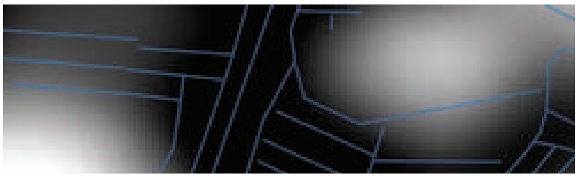

Figure 1: The colors of the cells in the image reflect density values. Dark colors represent high density of ditches and light colors low density.

3 Results

Total length of digitized ditches is 29,700 km. The distribution of the ditches proved highly clustered (Figure 2) which reflects the location of former wetlands and the position of farms. The highest density is usually closest to farms, where land has been drained for cultivation.

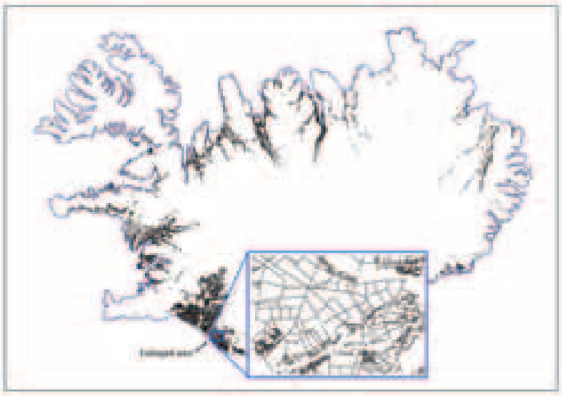

Figure 2: Ditches in Iceland. Inside the box is an enlarged area showing details of the network.

The pixel values in the image that display the outcome of the density analyzes are continuous and they can be further split into other values showing the density significance. Areas where the density was less than 0.1 km/km^2 are excluded in the comparison below, 111 km of ditches where thus excluded.

The total area with ditch density greater than 0.1 km/km^2, is 5 837 km^2. Included in this number is land which was dry before the excavation of the ditches and land were the ditches did hardly have any influence and land is still wet. The total area influence by ditches is accordingly overestimated. In other cases some areas have been encircled by ditches and part of the land drained, but not included in the total area due to distance between ditches (Figure 3). The area of drained land is thus underestimated.

A query operation was applied to the density raster image and the values split to equal interval classes. In Figure 3 are the classes shown as polygons on Spot image.

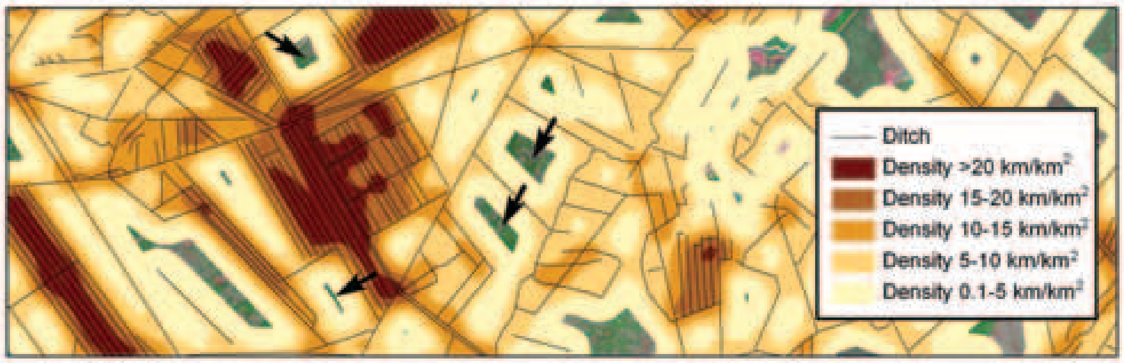

Figure 3: Satellite image with overlaying classes from the ditch density analysis. Black arrows point to some areas which are encircle by ditches but are not included in the total area affected by draining according to this approach.

The results show that the largest part of the area (56.3 %) affected by ditches (according to the definition >0.1 km/km^2) is with low ditch density, less than 5 km/km^2 (see Table 1). In addition 25.9 % of the total area is with density between 5–10 km/km^2. Only 17.8 % of the area influenced by draining has density more than 10 km/km^2.

Table 1: The distribution of ditches density, shown in equal interval classes

Density km/km^2	Area km^2	Ditches	% Ditches lenght km	% Area
0,1–5	2930	1780	6,0	56,3
5–10	1346	11418	38,6	25,9
10–15	565	8466	28,6	10,9
15–20	261	5332	18,0	5,0
>20	101	2593	8,8	1,9
Total	5203	29589	100	100

4 Discussion

Total length of the digitized ditches is about 2 000 km shorter than the total length according to the Farmers Association documentations and the water system map from Loftmyndir ehf (2009). It indicates that there are some ditches missing from the map and that it needs to be improved. The reason is probably the resolution of the Spot images. It is sometimes hard to tell if a feature in the image is a ditch or some other linear feature, such as a fence or track. In some other cases a linear objects might wrongly be mapped as ditches.

The digital ditches map gives a good overview of drained areas in the country. It locates the drained areas and provides information on how comprehensive the draining is.

By comparing the ditch map with a vegetation map it is possible to analyze how much of the drained areas are used for cultivation and the type of vegetation on the remaining drained areas.

The ditch density analyze provides important information on the intensity of the draining in each place. The results indicate that a large part of the area affected by drainage has diffused draining systems and probably not sufficiently drained to be applicable for cultivation. It makes it feasible to search for areas which can easily be restored as wetlands. That might by e.g. areas which are semi-dry and with low density of ditches. Additionally, the density of ditches reflects, up to a certain point, the investments in the draining and how promising a particular area is for reclamation and the cost appending.

By restoring the drained wetlands, considerable reduction in greenhouse gas emission (GHG) can be achieved, because large emission of greenhouse gasses is one of the side effects of drainage. In Iceland's 2008 submission to the United Nations Framework Convention on Climate Change (UNFCCC), emission from drained wetlands was the single largest component, emitting 1/3 of all reported emission (Hallsdóttir et al. 2007). The Icelandic government has, in its long term climate change policy, included wetland restoration as one option in reducing the national GHG emission and in the process of post-Kyoto climatic agreement, proposed wetland restoration to be included as one of eligible land use options (United Nations Framework Convention on Climate Change 2008).

5 Conclusions

The comparison of the digitized ditches map to other available data indicates gaps in the AIU ditch map. The map needs to be revamped and it's reliability assessed through ground-truth data.

The density analysis gives important information about the intensity of the drainage. Assuming wetland as disturbed, if the ditch density exceeds 0.1 km/km^2, then the total area drained or disturbed is 5 837 km^2, which is larger number than previous estimates indicates. Further research is needed to define which areas can be considered fully drained and how effective the drainage is in other areas.

Acknowledgements

Agricultural University of Iceland brings special thanks to the staff of the National Land Survey of Iceland, which digitized part the ditches.

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PINE REVEGETATION OF SANDY SHORES AT TERSKY COAST OF THE WHITE SEA, KOLA PENINSULA

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1 Introduction

The aim of our research is the assessment of pine forests established in desert seaside ecosystems at Terskiy coast of the White Sea (southern Kola Peninsula, Russia). More than 20 thousand hectares of sands which are subject to erosive processes are present at the coasts of the White Sea. Constant processes of movement of sands by wind form small hillocks. One of largest sand hills is located in the mouth of the Varzuga River at Terskiy coast, and is known as Kuzomenkie sands with area over 2.2 thousand hectares. This «desert» was formed because of adverse natural factors and economic activities: cattle breeding, wood cutting and forest fires (Cornelissen et al. 2001; Integrated Regional Impact Studies in the European North 2002). Sands advanced towards a channel of the Varzuga River and have changed hydrological regime in its mouth.

In 1980 replanting of trees at the Varzuga River coast has been started to stabilize the coast. *Pinus sylvestris L. Lapponica* was chosen as the basic tree species. Also *Juniperus sibirica Burgsd, Betula pubescens Ehrn and Leumus arenaris (L) Hochst.* were planted to promote higher acclimatization of plants.

2 Material and Methods

Study of structure and morphometric parameters of pine plantings was conducted in 2004–2007 in test areas 20x20 in size for forests of four different ages: plantings of 1985, 1990, 1995, 2000. In each area geobotanical descriptions were made and morphometric characteristics of the trees growing in groups and of single trees were described. The following parameters were measured: height of trees, diameter of trunk at root and at height of 1.3 m, annual linear growth of trunk and age of needles. Diversity of species has been also estimated. In total data for 500 trees were statistically analyzed.

3 Results

The aim of our research is the assessment of these pine forests established in desert seaside ecosystems at Terskiy coast of the White Sea. As a result more than 60 hectares of plantings have been created and they have established well, at present forming 15–20 years old pine forests.

The height of trees varied from 0.5 up to 3.5 meters. At all test areas height of the trees growing in groups exceeded height of single trees in all years of planting. Significant differences in height of the trees growing in group and separately appear when they reach 10 years of age (fig.1a).

Diameter of trunks at root varied from 1 up to 9.1 cm (fig.1b). For trees growing in a group diameter of their trunk at root is more than for separately standing trees of the same age. This distinction becomes significant when trees reach 15 years of age.

The annual linear growth of trees trunks measured in 2006 varied from 13.1 up to 24 cm. The linear growth of a trunk increases with age. In plantings of 2000 it was 13.1 cm, and in plantings of 1985 it was 24 cm (fig.1c). The most appreciable distinctions are characteristic for plantings older than 10 years.

The age of needles changes from 1 year to 4 years. For young plantings (of the year 2000) the age of needles on average is 1 year. For adult plantings the life of needles increases considerably (fig.1d). The age of needles for the trees growing in groups is almost 2 times more than for single trees.

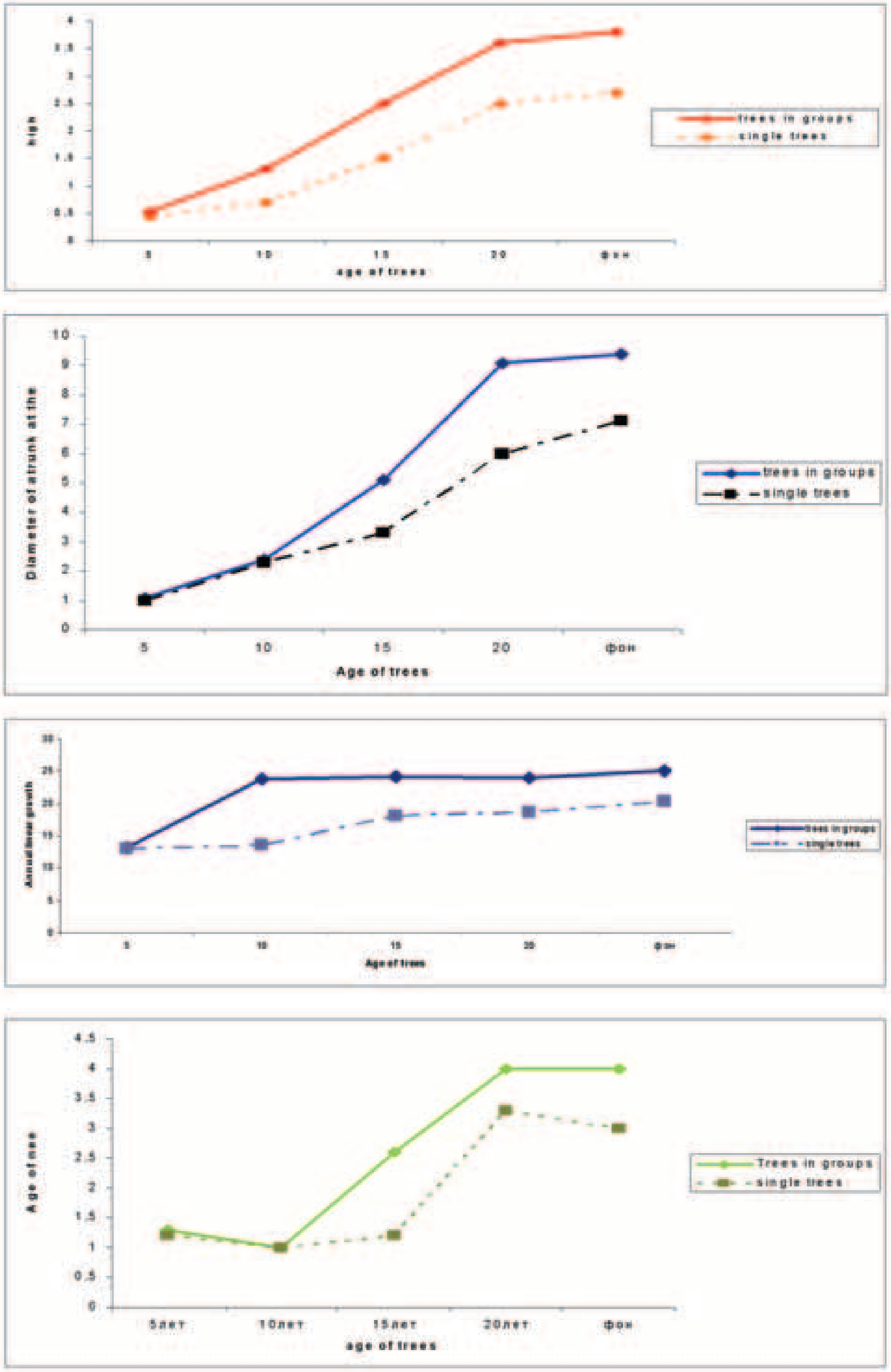

Figure 1: Morphometric characteristics: a – height of trees; b – diameter of the trunk at the root; c – annual linear growth of the trees trunks; d – age of needles.

Specific phytodiversity increases from 3 species in plantings of 2000 up to 6 species in plantings of 1985. *Rumex acetosa and Thymus L.* prevail among the new species in young plantings.In adult plantings, *Empetrum nigrum, Vaccinium uliginosum, Vaccinium vitis-idaea, and Calluna vulgaris* are present, i.e. plants typical for northern pine woods (Figure 2).

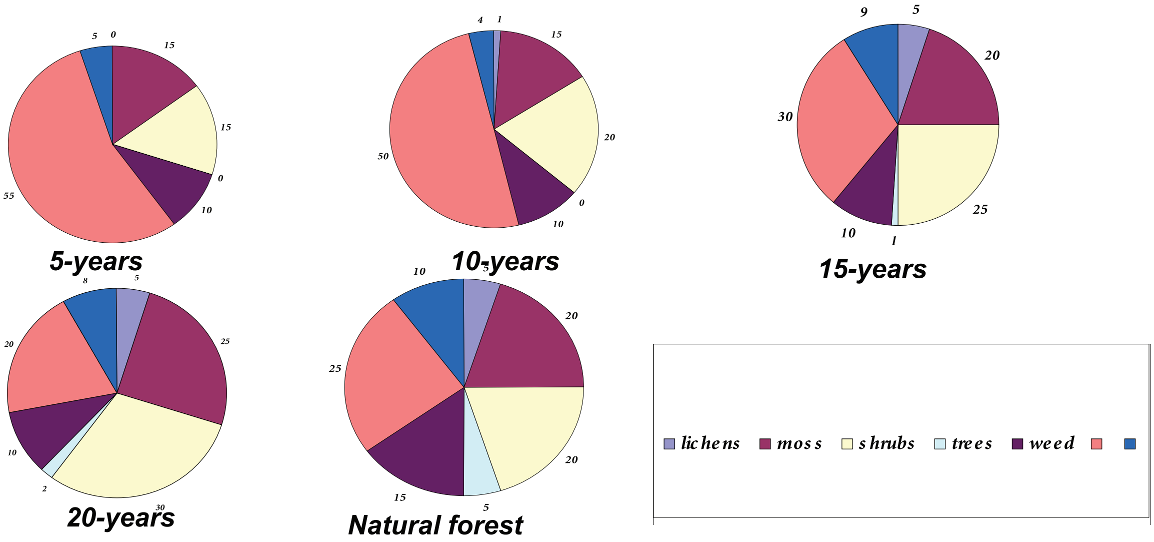

Figure 2: Phytodiversity in plantings and typical for northern pine woods.

4 Conclusion

Thus our research results demonstrate high efficiency of pine plantings on sands, presenting opportunities for solving the problem of erosion development by these methods for the entire Tersky coast (Figure 3).

Figure 3: Planting of 1985 year.

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LARGE-SCALE VEGETATION MAPPING IN ICELAND

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Abstract

Vegetation mapping in Iceland started in 1955 at the Agricultural Research Institute (ARI). The main purpose was to determine the carrying capacity of the vegetation of the grazing areas in the central highlands and thus provide a basis for their management. The vegetation was classified into six main vegetation complexes: Dryland vegetation, wetland i.e. fringes, sloping fens, level fens, aquatic vegetation and sparsely vegetated land. The main vegetation complexes were divided into 16 orders which again are divided into 98 sociations, the smallest units used. These units, which were developed by the botanist Steindór Steindórsson, are based on growth forms and dominant species of vascular plants in the upper layers of the vegetation. Fieldwork in vegetation mapping has now been completed of more than two thirds of the country. The central highlands are mostly completed but more than half of the lowland still remains. In 1995 the Icelandic Institute of Natural History (IINH) took over the task of vegetation mapping in Iceland from ARI.

1 Introduction

I will first describe and discuss large-scale vegetation mapping in Iceland as well as the vegetation legend used. Thereafter I will briefly explain how the vegetation mapping in Iceland is conducted and provide a short report on small-scale mapping and mention the habitat type mapping project which is closely related to the vegetation mapping. Finally, I will give a short report on our vegetation mapping in Greenland.

2 Large Scale Mapping

2.1 The Vegetation

The botanical composition of the current vegetation in Iceland represents only partly the potential or climax vegetation of the country. This is mainly due to an extensive woodland clearance and long lasting sheep grazing, which has resulted in large-scale damage of the vegetation cover and serious soil erosion in parts of the country. Unfavorable climatic conditions and a short growing season, especially in the central highlands, make the vegetation in Iceland very vulnerable and easily damaged by heavy grazing. Additionally, the volcanic soils of the country are prone to erosion and, therefore, overgrazing can induce soil erosion in a relatively short time. Due to improved climatic conditions we can however notice progress in vegetation cover and plant composition over the last two decades.

2.2 Vegetation Mapping

Vegetation mapping in Iceland started relatively late. In 1955 the Department of Agriculture of the University Research Institute, later the Agricultural Research Institute, started field work for a map of the actual vegetation of the highland common grazing area Gnúpverjaafréttur in South Iceland. Most of that area lies 300 m above sea level (Jóhannesson & Thorsteinsson 1957).

The overall purpose of the mapping was to determine the sheep carrying capacity of the vegetation of the central highlands, an area of about 40,000 km^2. Reliable information on plant communities was needed to assess nutritional value of the vegetation for sheep grazing and thus provide a basis for sustainable use and management of the highlands.

2.3 Vegetation Classification

The legend was defined and described on the basis of botanical research conducted over several decades by the botanist Steindór Steindórsson, an advisor to the mapping team from the beginning to 1985.

These units are based on growth forms, dominant and characteristic species of vascular plants in the upper layers of the vegetation and, therefore, considering mosses and lichens only to a limited degree. The main vegetation complexes were divided into 16 orders which again were divided into 98 sociations, the smallest units used. Vegetation orders were delineated in accordance with physiographical characteristics, while the smaller plant communities were classified according to dominant species of vascular plants. Borders between plant communities often tend to fuse. On the Icelandic vegetation maps complexes composed of a mosaic of two or more communities often cover a given mapping area.

Following are the main structures of the plant communities as described by Steindór Steindórsson (Steindórsson 1975 & 1981), revised and slightly simplified by a group of specialists in 1991-1993, (Einarsson 1994 & 1995) and present author:

DRYLAND VEGETATION
Moss heath

Heathland

1. dominated by *ericaceous* dwarf shrubs
2. dominated by *Betula nana*
3. dominated by *Salix* spp.
4. dominated by *Kobresia myosuroides*
5. dominated by *Juncus trifidus*
6. dominated *Carex bigelowii*
7. dominated by various species of lichens and dwarf shrubs

Wood- and shrubland

1. *Betula pubescens* woodland
2. *Betula pubescens* and *Salix phylicifolia* shrubland

Grassland and forb meadows

1. Grassland vegetation
2. Forb meadows

Cultivated land

WETLAND VEGETATION

1. Fringes (moist land)
2. Sloping fens
3. Level fens
4. Aquatic vegetation

SPARSELY VEGETATED LAND.
Land with sparse vegetation, (<10% vegetation cover) both in lowland and mountain areas are divided according to the underlying substrate into 14 substrate types, such as gravelly flats and riverplains, screes, cliffs and rock-walls. Non vegetated cultural land (e.g. roads, buildings, mines) are also included within this category.

2.4 Vegetation Mapping for Grazing Management

In the latter half of the 1950s, some additional field work was carried out in neighboring areas to Gnúpverjaafréttur, but no additional maps were published. In 1961, work on vegetation mapping began again with the plan to cover the entire country, with the same principal objectives as before. Using the same scale as earlier, 1: 40,000, would require 289 maps to cover the whole of Iceland. Over the next 20 years, this ambitious plan, lead by Ingvi Thorsteinsson with the continuing guidance of Steindór Steindórsson, was one of the major programs of the Agricultural Research Institute. Initially, the main emphasis was placed on mapping of the commons of the central highlands as a basis for grazing management (Thorsteinsson 1981).

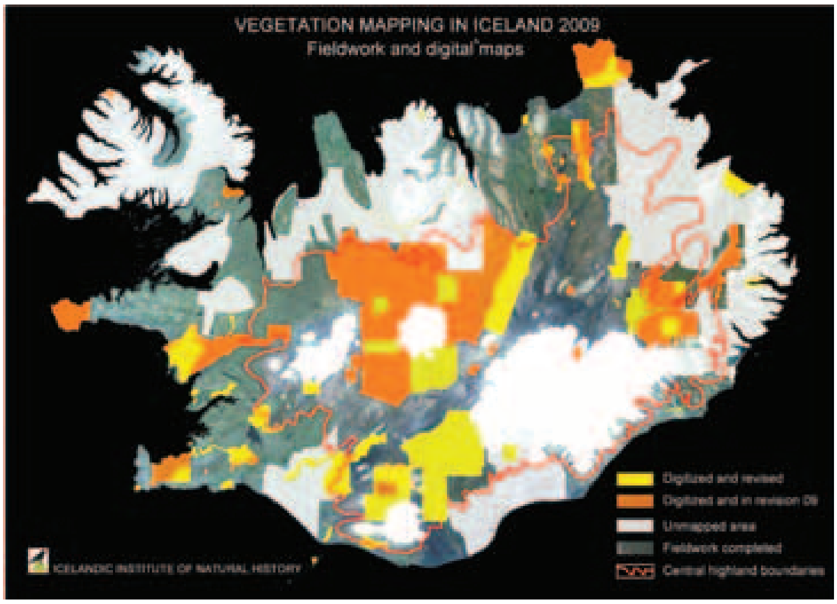
Despite limited funding at times, the mapping work proceeded relatively well, and around 1980 most of the central highlands and some parts of the lowlands had been mapped. Following 1980, mapping of the lowlands continued, but mapping work gradually decreased after 1990 due to lack of funds, caused by an overall decline in sheep farming and grazing pressure and thus decreasing demand for vegetation maps.

Publication of the maps did not proceed with the field work. So far, only 64 maps, in the scale of 1: 40,000 and covering 29,000 km² of the central highlands, have been published. An additional 32 maps of the central highlands were prepared, but not published. Furthermore 39 maps of lowland areas have been published, where larger scale maps are needed for planning or other land use management. Those maps are showing property, districts, and municipal boundaries (Gudbergsson 1981).

2.5 Vegetation Mapping for Environmental Work

In 1995, the Icelandic Institute of Natural History took over the task of vegetation mapping from the Agricultural Research Institute. Since then, the main thrust of the work has been to revise previous maps as a basis for environmental impact assessments of development projects in both highland and lowland areas. At the same time, budgets for traditional vegetation mapping have become even scarcer than before.

Field work for vegetation mapping has now been completed of more than two thirds of the country (see figure). The central highlands are mostly completed but more than half of the lowland still remains unmapped. For the last two decades 27% of the mapped area has been digitized and updated with the aid of new orthophotomaps and Spot-5 and Landsat satellite images.



In the early 1990s the vegetation mapping project in Iceland was computerized. So far, we have mainly used two mapping- and geographic information systems (GIS) software packages, Microstation from Bentley and Arc Info and Arc GIS from ESRI. In 2004 we started using imaging software from Erdas as well.

Until 1997, vegetation mapping was based on aerial photographs of various dates and scales as well as on AMS map series in the scale of 1: 50,000. Since then digital orthophotomaps, mainly with 0.5 m resolution, have been used with increased success. Recently we have begun the use of remote sensing data (Spot-5) to improve and verify the mapping work. The Spot-5 satellite, launched in 2002, has greatly improved remote sensing capabilities: image resolution is now to 2.5 meters. This creates new possibilities in cartography and in the collection of geographical information, although it does not substitute the orthophotomaps. The entire country (103,000 km²) has already been covered by sixty Spot-5 images. The National Land Survey of Iceland has bought the images together with IINH and other institutes and municipalities. The goal is now to complete the digitizing of all our vegetation material in the central highlands by the end of 2010 and to store the data in the IINH databank. Demand for digital vegetation maps of Iceland has never been greater than now.

As described above, the objective of the vegetation mapping program was initially to provide a basis for calculating the carrying capacity of sheep grazing areas. The vegetation maps have become increasingly valuable for planning and monitoring other land-uses and for environmental impact assessments. Vegetation maps also serve as historical records for the future.

3 Small Scale Mapping

In 1998, an overview Vegetation Map of Iceland (1: 500.000) was published by IINH (Gudjonsson & Gislason 1998). The map was generated with the help of Landsat Satellite Images (1: 250,000) and based on all vegetation data available at the time. Before that Iceland had been included in maps covering the Nordic Countries or the whole of Europe. The Vegetation Map of the Council of Europe Member States in the scale 1: 3,000,000 was published in 1979 and revised in 1987 (Påhlsson 1994). The map of the Physical Geographic Regions mainly based on natural vegetation was published by the Nordic Council of Ministers in 1983 (Nordiska Minesterrådet 1984). Maps of the Natural Vegetation of Europe including Iceland were published in the year 2000 in two scales, 1: 10,000,000 and 1: 2,500,000 (Bohn et al. 2000).

The Icelandic Forestry Research Institute has produced a map of all recent forest plantations and revised the map of natural birch woodlands in Iceland (Snorrason & Kjartansson 2004).

The European CORINE Land Cover Project in Iceland started in 2005 in cooperation between the National Land Survey of Iceland, University of Iceland, Agricultural University of Iceland and IINH. The map, which is now completed, refers to the years 2002 and 2006. It is mostly based on Landsat and Spot images interpretation.

Also IINH took part in compiling the Circumpolar Arctic Vegetation Map in the scale 1: 7,500,000 which gave us the first relatively detailed holistic view of the vegetation of an entire global biome (CAVM 2003). Most recently a new initiative has been started for a Circumboreal Vegetation Map that will link the CAVM and the boreal forest.

Finally an unpublished theoretical map was compiled by Eythor Einarsson and Einar Gislason «Vegetation in Iceland at the Age of Settlement» (Einarsson & Gislason 1998). It is conjectural based on the Overview Vegetation Map from 1998.

4 Habitat Classification and Mapping

In recent years vegetation maps have been used as a base for large scale habitat classification and mapping programs. For the field study, a stratified random sampling has been used. A vegetation map of each area is explored and the existing plant communities subjectively classified or transferred into preliminary habitat types. Based on this classification, a new map of each area is produced showing the preliminary habitat types. Plant communities that are most similar to a particular habitat type are then grouped together to form a specific type. Classification of about 400 vegetation transects from several highland areas has revealed 24 different habitat types (Magnússon & Magnússon 2002).

5 Vegetation Mapping in Greenland

In the years 1977 to 1981 the vegetation of 4000 km² of land in South-West Greenland was mapped with the same method as had been used in Iceland. The mapped area covers most of the vegetated boreal area of Greenland. The goal of the mapping and corresponding research, was to find out how much the sheep range and sheep farming could be increased without permanent effects on the vegetation cover. The project was carried out as teamwork between the Research Institute in Upernaviarssuk in Greenland and the Agricultural Research Institute in Iceland. The director for the project was Ingvi Thorsteinsson from Iceland. The total number of maps was 35 and they were processed in the scale 1: 20,000. In the beginning the area of the vegetation classes and range fields was measured by a computerized digitizer, but the maps were not published. As a co-operative project between the Greenland Institute of Natural Resources and the Icelandic Institute of Natural History all the vegetation maps of South-West Greenland have now been computerized and linked to a database.

6 Conclusions

Although considerable work remains, much has been accomplished to date in detailed vegetation mapping of Iceland. A substantial amount of data has been gathered. Information on vegetation also reveals other important aspects of natural features. Once digital vegetation maps in high resolution have been made, it is possible to simplify vegetation association in many ways in order to make smaller scale vegetation maps of larger areas.

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THE ICELANDIC GEOGRAPHIC LAND USE DATABASE (IGLUD)

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Abstract

In this paper the objectives and methods applied to construct a geographic database for Iceland are described. In the database all six top level land use categories and some subcategories requested by the UNFCCC inventory are geographically identifiable. The validity of the field sampling is tested through comparison with elevation models. The utilization of the field data is demonstrated through examples.

1.1 Introduction

One of the main commitments of signatories of the UN-Framework Convention on Climate Change (UN-FCCC) is to report all anthropogenic emission by sources and removals by sinks using comparable methodology.

In the inventories anthropogenic emission is divided into six sectors, i.e. Energy, Industrial processes, Solvents and other product use, Agriculture, LULUCF and Waste.

The methodology for reporting Land use, land use changes and forestry sector (LULUCF) is described in IPCC Gudiance for National Greenhouse Gas Inventory (IPCC 2006) (hereafter IPCC Guidance). In the guidelines six top level land use categories are defined; Forest land, Cropland, Grassland, Wetland, Settlement and Other land. Each of these land use categories can then be divided into subcategories, depending on conditions in each country. Subdivision should reflect land cover, management regimes, climate zone or other criteria affecting the greenhouse gas emission or removal pertinent to each country. Within each category there are five carbon pools defined which can be affected by different land use. The changes in these pools are reflected in CO_2 emission or removal. Land use can also affect emissions of other greenhouse gases, such as CH_4 and N_2O, and these needs to be reported as well.

1.2 Objective

The objective of the Icelandic Geographic Land Use Database (IGLUD) is to compile information on land use and land use changes compliant to the requirements of the IPCC Guidance (IPCC 2006). The categorization of land use also needs to be, as much as possible, based on existing information and adapted to Icelandic land use practices. Important criteria is that the database must recognize the land use practices most affecting the emission or removal of greenhouse gasses, and changes in extension of these. The defined land use classes need to be as much as possible recognisable both through remote sensing and on the ground. This especially applies to those categories not otherwise systematically mapped and for which information is available.

Another important objective of the IGLUD is to ensure that all six main land use classes of the IPCC Guidance are geographically identifiable. According to the Guidance subdivision of the main land use categories within the database should either be identified geographically or to the relative division within a region. Relative division can either be based on ground surveys or other additional information.

2.1 Different approaches and existing land use information

The IPCC Guidance defines three different approaches for reporting land use and land use changes. (1) Basic Land use data: The area of each category is reported each time. The land use changes reported are the changes in the area of each category irrelevant of the origin of the changes. (2) Survey of land use and land use changes: The same as basic land use data but origin of changes in each category is reported. The area of Forest land converted to cropland and vice versa is reported. (3) Geographically explicit land use data: Each land use category and changes within are geographically identifiable at each time.

In selecting the approach, existing data, other resources and the accuracy required have to be considered.

Iceland has elected one of the eligible activities under Article 3.4 of the Kyoto Protocol, this requires spatial explicit data. The possibilities within Iceland to decrease current emission through improved management, both in grazing land and wetland, are considerable. Large areas of grazing land are severely degraded but still harbour a large soil carbon pool and wetlands have been drained extensively. The need for spatial identification of some land use categories is thus presently needed and will probably be for additional categories in near future.

Secondly, history of land use recording in Iceland is very limited. Recent mapping efforts are generally based on satellite images and/or aerial photographs and the resulting classification exist in digital map covers. Thus, the history of land use recording, existing data and present and foreseen LULUCF inventory requirements all favour recording the land use data with geographically identifiable land use units.

2.2 Methodology

The construction of a geographical database containing all six main land use categories and some subcategories of the LULUCF inventory as spatially recognisable units, involves several phases:

1. Compilation of existing geographical data
2. New mapping efforts
3. Collection of new data
4. Compilation of additional data and utilization of new data sources
5. Converting land use information to GHG emission/ removal.

Compiling existing geographical data

Each top-level category is separately compiled from existing data, based on definition of the relevant category and properties of the individual classes in the data source.

Example: NYTJALAND is a farm-based land-cover database classifying the land into ten classes according to both vegetation coverage and type (Arnalds & Barkarson 2003). One of the criteria used in classifying land to the LULUCF land use category Grassland, is that the total coverage of vascular plants is more than 20 %. Accordingly all the NYTJALAND classes meeting that criterion are compiled to the Grassland category. Other data sources are then treated similarly.

The result is a map layer including all map units which can be considered as candidates to the category. These map layers are then merged together applying predefined hierarchy rules.

New mapping efforts

Some of the land use categories which are important to the LULUCF inventory are not represented in existing data. Therefore mapping of these categories is needed. Mapping of four land use categories has been initiated for that purpose.

Drained wetland, being the second largest source of greenhouse gas emission in Iceland, is an important component in the LULUCF inventory. No maps were available for this category. The Agricultural University of Iceland (AUI), in cooperation with the National Land Survey of Iceland, has digitised all wetland drainage ditches recognizable using SPOT satellite images supported by aerial photographs.

The AUI has likewise digitized all cropland, as no maps were available for that LULUCF top-level category.

Two important land use categories in relation to the LULUCF inventory are Forest land and revegetation activity. The Icelandic Forest Service and the Icelandic Soil Conservation Service are presently mapping these categories respectively and refining the existing maps.

Collecting new data

Three types of new data are needed. 1. Data for estimating different carbon pools of the land use categories. 2. Data for supporting the land use classification. These data are needed for both ground truthing of present classification and to support subdivision of land use categories. 3. New data is also needed for identifying changes in land use from one time to another. To this end field data (see below) has been collected and new satellite images will be classified applying comparable classes as in the existing data. Classification of new satellite images has not yet started.

Compilation of new additional data

Several sources of data exist that do not directly represent land use in the same resolution as the data compiled for each land use category. These data sets are never the less valuable in establishing changes in management and land use intensity.

This kind of data is e.g. agricultural statistics such as livestock changes and crops harvested. These data have resolution down to municipal level and sometimes to farm level. Another example of supporting data is existing soil maps.

Conversion of land use data to GHG emission/ removal

The core of LULUCF inventory is the transformation of land use information into estimated GHG emission and removal. Different tiers are accepted for this conversion ranging from use of default emission factors to process based modelling or direct measurements. Different tiers can be applied to different land use categories. Using process based models for emission calculations requires additional data in the form of driving variables with appropriate time resolution.

2.3 Field sampling

The opted approach for field sampling was using clusters of sampling points placed on a grid system covering the whole country. The starting point of the grid system was selected randomly. All points below 400 m a.s.l. on a grid with 24 km squares were selected and all points at 400 m or more a.s.l. on a grid with 48 km squares. From these points clusters of sampling points were laid out. For points on the 24 km grid each cluster contained 20 points in two lines from east to west with 2.5 km intervals. Distance between points on the same line is 500 m. For points on the 48 km grid each cluster contained 12 points in two lines with 2.5 km intervals.

To test the validity of this method the points selected were used for predicting the division into altitude intervals and the results compared to actual intervals as derived from 20 m elevation model. The area of altitude intervals estimated by; all cluster points in present setup as described above, by doubling the lowland (< 400 m) clusters and by all points already visited, was compared to the intervals of the elevation model. The results are shown in table 1. Most of the altitude intervals are reasonably represented in the samples, although some predicted intervals do divert far from the actual size.

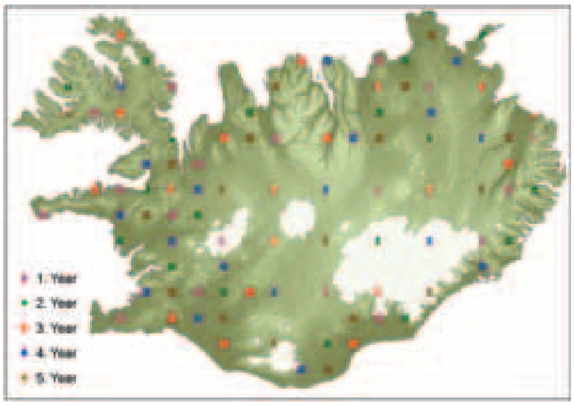

Figure 1. Map of Iceland showing all selected clusters

This comparison points out that the results obtained through this sampling method need to be controlled or supplement by other data sources and the land use categories badly estimated, identified and targeted specifically.

The location of each sampling point is preset as described above. The sampling point is defined as a circle w 3 m radius surrounding the sampling

Table 1. Results of comparison, of altitude intervals area (km^2) as predicted by sampling points, to elevation model.

Altitude interval	Elevation model	Present clusters	Double lowland clusters	Points already visited
0–100m	17.204	14.026	15.633	15.849
100–200m	8.142	8.120	8.759	9.157
200–300m	8.328	6.445	9.222	5.417
300–400m	9.721	10.199	9.490	8.736
400–500m	10.764	15.344	11.396	17.290
500–600m	11.337	8.759	12.037	9.539
600–700m	11.194	10.922	10.642	10.452
700–800m	7.594	6.751	6.041	9.075
800–900m	5.026	8.579	5.346	3.998
900–1000m	3.182	2.894	3.108	1.847
1000–1100m	2.417	2.753	2.416	3.705
1100–1200m	1.771	3.176	2.042	2.691
>1200m	6.158	4.870	6.704	.5082
total	102.837			

point. Within that circle the following attributes are recorded; Total vegetation cover, Extent of erosion spots, Hummocks, Land cover class of NYTJA-LAND, Homogeneity regarding coverage class, Average soil depth, Grazing marks and Index plants found inside the sampling point (Preferred grazing plants, Less preferred/not grazed plants). Overview photo is taken and soil down to 30 cm is sampled. Inside the 3 m circle vegetation in three 50x50 cm frames was recorded in more detail. Vegetation was identified to functional groups and total coverage of each group inside the frame determined. Two of the frames had fixed positions but one was randomly selected. Inside the randomly selected frame above ground biomass, covering living biomass, standing dead and litter, was sampled on 10x10 cm square. A photograph was taken of each frame.

3 Results and Discussion

The project is designed to yield two types of results i.e. land use classification data both geographically identifiable and relative size of land use categories, and also data on the size of different carbon pools inside each land use category. The project enables comparison of two approaches of land use classification i.e. the classification arrived at through compilation of available geographical maps and classification according to field data. To illustrate this, the recognition of the Grassland land use category in field is compared to the compiled map layer.

The criterion for a field point to be recognized as grassland is that the coverage of vascular plants is 20 % or higher. Out of 476 field points visited in 2007 and 2008, 262 were recognized as grassland, and 224 or 85 % of those were inside the grassland map layer. Of the points visited 369 were inside the grassland map layer, 224 or 60 % were identified as grassland in the field. Accordingly not all grassland is identified on the map layer and the map layer includes land not recognized as grassland in the field.

Field data can be applied to determine the relative division size of subcategories. One possible subdivision of grassland is to subcategorize according to the presence or absence of erosion. In the field erosion spot coverage is identified to six classes. The relative division of these classes can be applied to the grassland map layer to estimate the total coverage of each class. According to this 58 % of the points identified in field as grassland have no erosion spots. The area of the Grassland category was estimated for the LULUCF inventory 2009 submission to be 52 732 km^2, 42 % or 22 147 km^2 are subsequently with erosion spots. This can be compared to the mapping of soil erosion in 1991–1997 (Arnalds et al. 2001) where 28 000 km^2 were mapped as land with erosion spots.

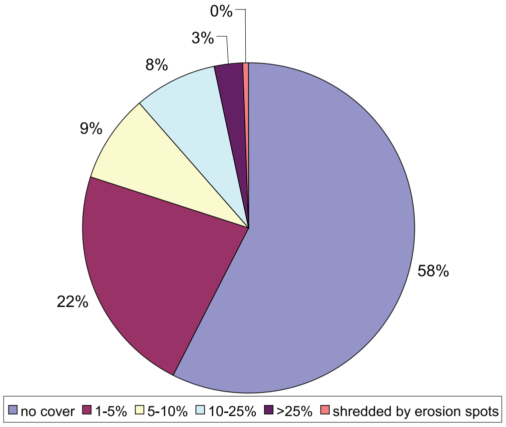

Figure 2 Relative cover of erosion spots at field sampling points

The significance of this subdivision can be evaluated by comparing the amount of carbon stored in the above ground carbon pool (AGCP) of each category.

The amount of carbon in AGCP does to some extent correlate with the coverage of erosion spots. (R^2=0,544) This is to some extent trivial as erosion spots have zero AGCP, but also the extent of erosion spots reflect general degradation of the land and so would the size of the AGCP. Above ground pool also varies according to vegetation type where e.g. land where mosses are dominating has relatively large above ground carbon pool. Erosion spots are thus an important classification factor but other indicators are needed for relevant subdivision of the grassland land use category.

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CLASSIFICATION OF VEGETATION IN RED DEER HABITATS IN NORWAY

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Abstract

The vegetation is mapped in three areas on the west coast of Norway – totaling 20 000 km^2. These maps together with other databases will explain the coherence between different habitat preferences and GPS tracking positions of red deer in the main project «Natural and farmed habitat as a basis for production of red deer in Norway». The field observations provide a good basis for image interpretation of vegetation types by ecologic variables such as soil depths, nutritional soil value, and water content. Landsat 7 and SPOT 5 satellite images are used in the classification of vegetation types. Vegetation luxuriant is a main category. If it is difficult to separate the vegetation type in the real world, you should meet the same challenge in the image classification, on the object level. Our material consists of lots of objects in irregular and complex nature. This is documented in the confusion matrix and in the manual examination of all the field observations (training objects). Our map and nature correspond chiefly.

1 Introduction

My task in the main project «Red Deer – Area», «Natural and Farmed Habitat as a Basis for Production of Red Deer in Norway» is to deliver a wall-to-wall area type map (vegetation map) in three areas of the west coast of Norway. Our vegetation map and several other databases like elevation maps (slope and aspects), residential maps, and agricultural maps, are used to explain the coherence between different habitat preferences and GPS tracking positions of red deer.

My experience from traditional field-based vegetation mapping from 1980 to 2006 is combined with new methods in image analysis. Different mapping methods were examined in 2005–2007 by the SATNAT program and other projects conducted by Leif Kastdalen. (Hjeltnes 2006a, Hjeltnes 2006b, Kastdalen 2009).

Figure 1: Three mapping areas on the west coast of Norway.

2 Material and methods

The mapping areas are situated on the west coast of Norway, totalling 20 000 km^2 with 10 000 field observations and 33 000 reference image objects (Figure 1). Notice that the field work does not supply sufficient reference data, hence image interpretation is very important. In contrast rich areas along roads, water bodies, and buildings (residence) are not classified by the image classification. The area of Sogn is finished Haugalandet is still ongoing.

Landsat 7 satellite images are used in the area of Sogn and Haugalandet. In Møre-Trøndelag, Spot 5 images are available. I prefer moderate image pixels size (5–15 m) to minimize shadow effects from vegetation and small detail in vegetation and soil surface. Several other databases are included in the image analyses: FKB situation maps describe water edges, roads and buildings. N50 topographic maps are used in areas where detailed FKB data are missing. DTM25 altitude maps contribute with altitude information. AR5 area recourse maps contribute with agricultural and forest maps. Geological maps give an indication of potential rich vegetation. Detailed colored air photos in stereo view and orthophotos collect detailed ground truth information. These images derive ecological and topographic information and provide accurate geographic localization.

The main tasks in the image classification:
Field work
Segmentation – the image object are created
Objects classification
- Choosing and optimizing features of image objects
- Identifying (classification) and control of training objects
- Nearest neighbor classification
- Manual control of the training objects

Classification control (omitted)
Image map – map database


Figure 2: One relative homogenous image object

2.1 Field work

In the field it is almost impossible to describe all variations in altitude and exposition in the Norwegian complex landscape. Time and monetary costs are too high. Accordingly, it is important to understand the main ecological parameters in order to identify a correct area type in areas not visited in the field. The main ecological parameters are identified as:
- Water content in the soil surface and ground water movement down hillsides
- Soil depths
- Nutritional soil value

A simple stereo instrument and aerial photos give an accurate geographical position of the field observations. The number written on the air photos are references to the observations in the field journal. The size of the numbers represents small or large areas respectively. The field observation comprises eight major area classes. They are subdivided in 4 parameters. Area type is defined by dominant species or group of species in 25 % horizontal cover intervals. The minimum horizontal cover is 10 %. The species are ordered in 3 levels of luxuriance (low – intermediate – high) The field work focuses on the categories marked in bold letters.

Major area classes:
1. **Mountain area**
2. **Forest**
3. **Bog**
4. **Open fields in forest areas**
5. Cultivated areas
6. Development areas
7. **Sparsely vegetated areas**
8. Water, snow and ice

Subdividsion of major classes:
- **Area type**
- **Ground vegetation luxuriance**
- Soil water content
- Age classes for evergreen forest

The luxuriance value corresponds to the poor-rich gradient in traditional classification systems (Rekdal & Larsson, 2005). An example is the intermediate rich blueberry vegetation dominated by *Molînia coerulêa,* which we identify as intermediate luxuriance vegetation. The poor-rich gradient is strictly connected to indicator species. We use instead the spectral characteristics in the satellite image to define the finale luxuriance value of image objects. The time of exposure of satellite images, air photos, and field work may differ sometimes by several years! By the *luxuriant* parameter it is possible to explain spectral conflicts between image objects. One species or group of species has sometimes more than one luxuriance value due to the phenomena listed below. A good example: *Molinia caerulea* grassland is typical classified as intermediate luxuriance vegetation. But in high mountain areas it is low and sometimes in fertilized areas it is high.

Luxuriance value varies according to:
Phenology
Drought, wetness, irrigation
Fertilizing, grazing
Fungal and insect attack
Mechanical attrition
Agricultural land use
Silviculture
Ageing (young – old)

2.2 Object based image analyses

The image objects are created in the segmentation process. A small scale parameter provides small image object sizes and thus spectral relative homogenous objects (Figure 2). The most common size is about 0.5–1.5 hectare. Object size and selection of features are critical for a good classification. Simple distance measures are used to describe geographical variation in vegetation. This is distance from coast and altitude above sea level. In this way it is possible to model local phenomena listed below: The *nearest neighbor* classifier is used to classify the satellite image. It takes into consideration slope and aspect together with a correction of differences in solar illumination («C-correction» (Song, 2001)).

Local geographic variation:

Vegetation sections and vegetation zones (Moen 1998)
Insects and fungus diseases
Rain and snow showers
Difference in agriculture traditions (Ex.: Goat and sheep grazing)
Geology
… Other

Training objects are classified in the office based on two geographical and several spectral features. To define the horizontal cover of dominant species we use continues gradients from 0 % – 100 % cover (Arrows in Figure 3). In this example (Figure 2 and 3) *Calluna vulgaris* cover about 60 % of the area of the candidate image object. Other heats represent about 40 % cover and Birch bushes 20 %. The luxuriance value is estimated to be relatively low. The red circle indicates the final classification of the object based on all relevant information, which includes forest map, area resource map, geological map, field observations, stereo aerial photo interpretation, and spectral characteristics of satellite image. Now it is time to choose a vegetation type in the legend. In the example, the type *heather with low luxuriance* is most appropriate. Finally every candidate object is tested against all other training objects (11000 objects) by the membership values (by the *Euclidian distance* of features). In the example, *Heather with low luxuriance* is the nearest *neighbor* and *birch forest with intermediate luxuriance vegetation* is less similar. In this test we use all information listed above. These operations represent about 75 % of the total work. The satellite image is finally classified by the *nearest neighbor classifier* based on all 11000 training objects.

3 Results and discussion

One cutout map from the municipality of Flora in the mapping area of Sogn (Figure 4) is classified based on 6000 and 11000 training objects. The main classification product is almost identical in both maps. But lots of complex objects, irregular objects, and error give a different result in some areas. These ambiguous areas are marked with red colour in Figure 4. This is a simple test of instability.

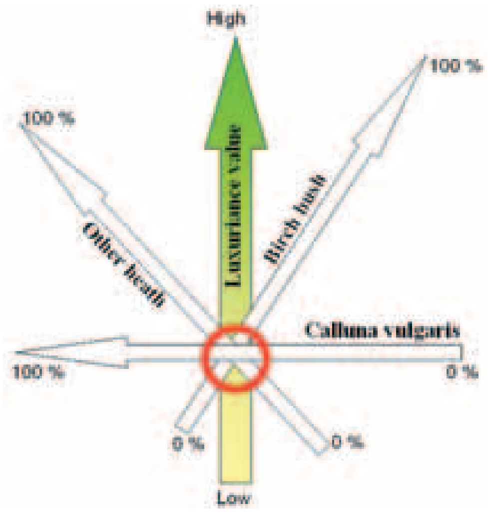
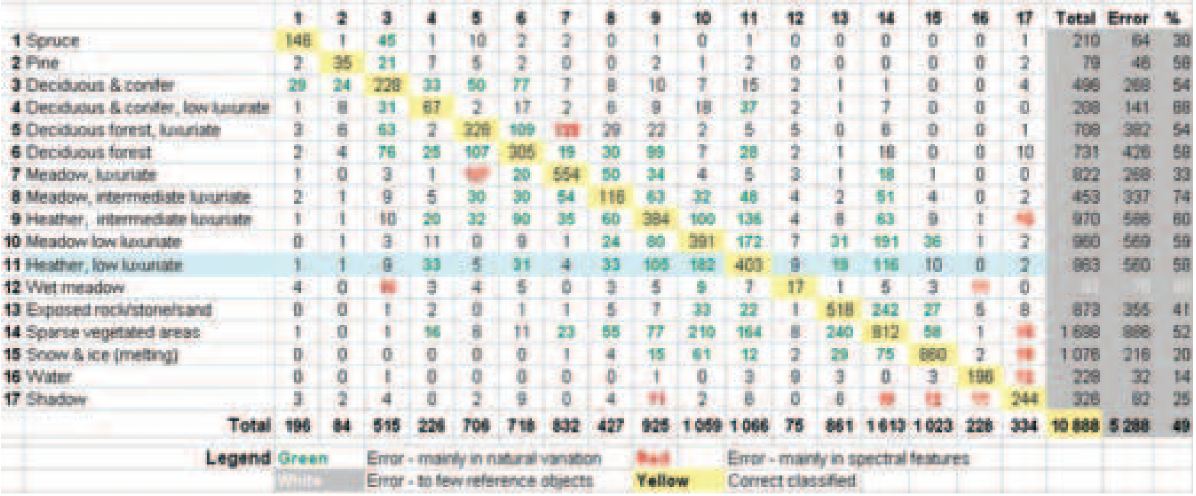


Figure 3: Classification of training objects

Figure 4: Ambiguous objects in classification marked with red colour. Topographic map behind the read image objects.

11000 reference objects are tested in a «10 fold cross validation» (Figure 5). 45 area classes are merged to 17 classes. Most snow and ice areas (mapped by snow index) and contrasting rich bor-



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total	Error	%
1 Spruce	146	1	45	1	10	2	2	0	1	0	1	0	0	0	0	0	1	210	64	30
2 Pine	2	35	21	7	5	2	0	0	2	1	2	0	0	0	0	0	2	79	46	58
3 Deciduous & conifer	29	24	228	33	50	77	7	8	10	7	15	2	1	1	0	0	4	496	268	54
4 Deciduous & conifer, low luxurate	1	8	31	67	2	17	2	6	9	18	37	2	1	7	0	0	0	208	141	68
5 Deciduous forest, luxuriate	3	6	63	2	326	109	[illegible]	29	22	2	5	5	0	6	0	0	1	708	382	54
6 Deciduous forest	2	4	76	25	107	305	19	30	99	7	28	2	1	18	0	0	10	731	426	58
7 Meadow, luxuriate	1	0	3	1	[illegible]	20	554	50	34	4	5	3	1	18	1	0	0	822	268	33
8 Meadow, intermediate luxuriate	2	1	9	5	30	30	54	116	63	32	46	4	2	51	4	0	2	453	337	74
9 Heather, intermediate luxuriate	1	1	10	20	32	90	35	60	384	100	136	4	8	63	9	1	[illegible]	970	586	60
10 Meadow low luxuriate	0	1	3	11	0	9	1	24	80	391	172	7	31	191	36	1	2	960	569	59
11 Heather, low luxuriate	1	1	8	33	5	31	4	33	105	182	403	9	19	116	10	0	2	963	560	58
12 Wet meadow	4	0	[illegible]	3	4	5	0	3	5	9	7	17	1	5	3	[illegible]	0			
13 Exposed rock/stone/sand	0	0	1	2	0	1	1	5	7	33	22	1	518	242	27	5	8	873	355	41
14 Sparse vegetated areas	1	0	1	16	8	11	23	55	77	210	164	8	240	812	58	1	[illegible]	1 698	886	52
15 Snow & ice (melting)	0	0	0	0	0	0	1	4	15	61	12	2	29	75	860	2	[illegible]	1 076	216	20
16 Water	0	0	1	0	0	0	0	0	1	0	3	9	3	0	3	196	[illegible]	228	32	14
17 Shadow	3	2	4	0	2	9	0	4	[illegible]	2	8	0	8	[illegible]	[illegible]	[illegible]	244	326	82	25
Total	**196**	**84**	**515**	**226**	**706**	**716**	**832**	**427**	**925**	**1 059**	**1 066**	**75**	**861**	**1 613**	**1 023**	**228**	**334**	**10 888**	**5 288**	**49**

Legend 🟩 Green: Error - mainly in natural variation; 🟥 Red: Error - mainly in spectral features
⬜ White: Error - to few reference objects; 🟨 Yellow: Correct classified

Figure 5: 10 fold cross validation of 11000 training objects.

ders derived from the map are not tested. The first impression seems to be a poor result. The overall error is 49 %. But most of the individual errors correspond very well to the experience from field work and the process described in chapter 2.2 (Figure 3). Figure 4 show an example marked with a blue line – *heather with low luxuriance vegetation*. 403 of 963 objects are correctly classified. But 182 objects are classified as *meadow with low luxuriance value*. In the real world these two vegetation types are difficult to separate in the mountain area, but well separated below. 116 objects are classified as *exposed rock/stone/sand*. These two vegetation types are difficult to separate, especially in the mountain area. 105 objects are classified as *Heather with intermediate luxuriance vegetation.* There are lots of object in these to vegetation types with small difference in *Euclidian distance* and similar appearance, especially in the mountain area. Different types of error are marked with different colours in Figure 5.

4 Conclusion

The vegetation map is divided into areas separated with distinct borders. In the nature you generally find continued variation along several gradients and invisible borders. If it is difficult to separate the vegetation type in the real world, you should meet the same challenge in the image classification, on the object level. If we get rid of training objects in irregular and complex nature we will get a better statistical result. But our material consists of lots of these objects – and so does nature! For example: Very different vegetation types such as birch forest and open heath are sometimes poorly separated both in nature and in the spectral characteristics of image objects. Poor (negative) statistical results in the confusion matrix may be good – good statistical results may be bad. Our map and nature correspond chiefly. Merging similar vegetation types may sometimes be a reasonable method.

Acknowledgements

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FERAL SHEEP IN COASTAL HEATHS – MAPPING THE QUALITY OF ALL YEAR PASTURES

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Abstract

We have mapped the quality of pasture resources for sheep grazing outdoor all year on ten localities along the west coast of Norway, using a classification scheme developed for this purpose. The classes reflect fodder value throughout the year. We performed an accuracy assessment, and identified possible sources of error. The accuracy is relatively low, and like others, we found that separating heath classes is a challenge. However, most errors can be explained by special mislocation and temporal change. Our further work with exploring grazing habits and landscape use of Old Norse sheep will include a GPS study of sheep movements overlaid with our pasture maps. We will update the map on that locality through field visits to enhance its accuracy.

1 Introduction

Coastal heathlands stretch along the west coast of Europe (Kaland 1974, Gimingham 1975,). Here, anthropogenic burning have created an open landscape dominated by heather, *Calluna vulgaris*. The coastal heathlands are today threatened by regrowth due to cessation of traditional management, but all year grazing by the tough Old Norse sheep, *Ovis aries,* may be an effective way to conserve these cultural landscapes. Such livestock management demands pastures with both summer and winter resources, abundant and of sufficient quality. As part of the research project *Feral sheep in coastal heaths – developing a sustainable local industry in vulnerable cultural landscapes*, we have mapped ten Old Norse sheep pastures in coastal heathlands along the south-west coast of Norway.

Pasture maps should comprise information about different fodder resources available throughout the year, and indicate management status, as this is important to pasture quality. The grazing habits of Old Norse sheep are believed to be closely linked to the dynamics of the coastal heathland system (Kaland 1974), where burning leads to alternating phases of grasslands and evergreen heather (Gimingham 1975). Old Norse sheep belong to a rare and ancient group of breeds, which differ from the more common domestic breeds both internally (Stenheim et al. 2003) and in outer physical properties such as fur, body size, as well as in behaviour, such as grazing selectivity (Steinheim et al. 2005), and is well suited for all year grazing. It tolerates high-fibre fodder, and can live off of the evergreen heather during winter. During summer, it prefers more nutrient rich grass areas and newly burnt patches dominated by herbs and young heather.

Different methods exist for remote mapping of agricultural areas in Norway, but none of these part out information on pasture resources through the year. Also, most of the standard methods, e.g Rekdal & Larsson (2005) and Fjellstad et al. (2004), are intended for national monitoring, and are too coarse-grained for our needs. Our study areas are within a single ecological system, on a narrower geographical scale, and we need a smaller minimum mapping unit. Here we present a new mapping scheme specifically for quantifying Old Norse sheep pasture quality in coastal heathlands.

A new methodology calls for an accuracy assessment. We partition the errors in our maps into errors caused by changes that have occured since the photo was taken, errors caused by spatial mislocation between aerial photograph and GPS field points, and errors caused by misinterpretation.

The maps will be used in the research project to understand more about the Feral sheep industry and possible challenges it faces. Later steps involve relating pasture quality information to sheep health data, in order to understand what properties of a pasture is optimal for the animals. Our pasture maps will also serve as a good basis for later studies concerning animal grazing preferences.

2 Materials and methods

Ten study sites, each the home range of a flock of Old Norse sheep, were mapped using manual interpretation of RGB aerial photographs. The mapping scheme was designed to represent differences in fodder resources and other factors that may influence the well-being of Old Norse sheep (Table 2). The underlying ecological gradients that separate these classes are moisture status and succession (i.e coastal heathland dynamics). In addition, a technical necessity was the delineability of each class in aerial photographs, and as the main reason for mapping was to compare stocks, it was necessary to only retain classes that were delineable at all sites. Our vegetation classes are listed in Table 1, along with information on why it was important to delineate this class, and which characters we used to identify the class in the aerial photos. A detailed account of the methodology is given in Kittelsen (2008).

Map accuracy was assessed on all but one locality by collecting 100 GPS points per locality (<100 on two localities) in a systematic sampling design (regularly spaced points along regularly spaced transects). Points where burnt areas and bare soil were detected in the field but not in the vegetation maps were classified as «change errors» – errors related to change since aerial photographs were taken. Points where the mapped vegetation was *present* in the map within the field area, but not *dominating* in the specific point, were identified as «mislocation errors». The remaining error is assumed to be interpretation errors. We did not correct the maps before validation; the accuracy is assessed for the first map draft.

Through other parts of the research project, lamb weights (spring, summer and autumn) have been collected on the same sites. We used regressions to find out if any variables extracted from our maps could account for differences in average lamb growth rates among localities.

Table 1: List of vegetation classes, criteria for distinguishing the different classes and for delineating features in aerial photographs

Vegetation class	**Argument for using the class**	**Characters distinguishing feature**
Bare rock	No fodder value.	Very bright signature compared to all other land cover types
Burnt heather and bare soil	Valuable as summer fodder in late summer.	Grey/brown to light green signature. Smooth texture.
Grass and pioneer vegetation	Valuable as summer fodder.	Green signature. No drainage patterns.
Mire	Assumed to be of low fodder value, but young graminoids might be valuable early in growing season.	Green, yellow or brown signature. In flat areas. Drainage patterns.
Heather dominated – moist (HM)	Important winter fodder. Different landforms, substrates and species than DM.	Dark brown signature. Coarse texture. Less dense than HD, substantial element of mire species. In flat areas, near mires.
Heather dominated – dry (DM)	Important winter fodder. Different landforms, substrates and species than HM.	Dark brown signature. Coarse texture. On hilltops and near rock.
Heather dominated – successional (HM or DM invaded by shrubs/trees)	May signify poor management. Low fodder value, but with edible species, especially in HM.	Areas of HD or HM where single trees occur. Coarse texture.
Forest and shrub	May signify poor management. Low fodder value, but with edible species. Important as shelter.	Different shades of green. Coarse texture. Tall.
Bracken	Low fodder value. Takes over valuable summer fodder areas. Problematic for management.	Very bright green.
Water	May be important as drinking sources. No fodder value.	Dark blue signature. Flat features. Crisp boundaries.
Developed areas	No fodder value.	Recognizable urban features.

3 Results

The heathland vegetation differs considerably among localities, especially the proportion of bare rock grass and pioneer vegetation (Fig. 1), and all classes were not present at all localities.

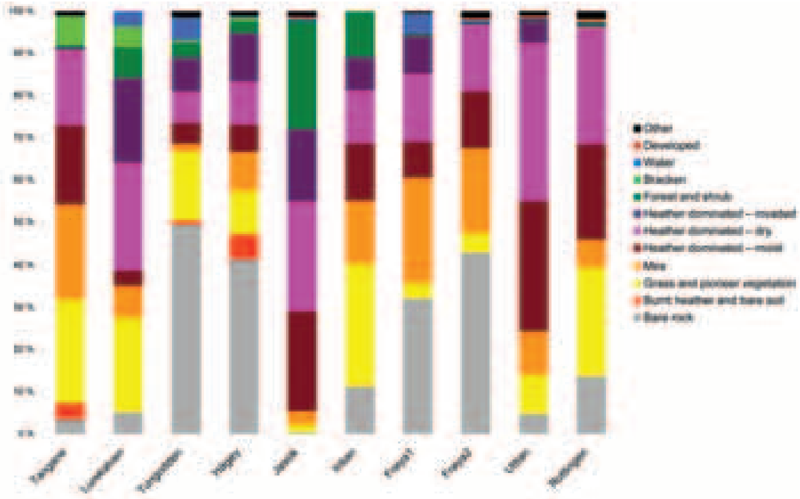

Figure 1: Vegetation composition.

Overall map accuracy ranged from 54 to 77 per cent, with a mean of 62 per cent. Change errors varied considerably between sites depending on management (notably, burning) and the age of the aerial photo, but averaged 6 % across sites. Location errors were more evenly distributed with a mean of fifteen per cent, and ranging from nine to twenty four per cent. After these two sources of errors have been accounted for, the remaining errors, which reflect misinterpretations of the aerial photographs during the classification process, ranged from 7 % to 30 % with an average of 17 % (Table 2). Error matrices show no consistent confusion between specific two by two classes, but that heather classes generally have lower accuracies.

A large number of variables were extracted from the maps, including proportional area of the different vegetation types. Higher average growth rates (=2.26, r^2=0.62, p=0.0066) are obtained in sites with a higher proportion of grass and pioneer vegetation. Increasing area of grass and pioneer vegetation *per animal* on the pasture did not have the same effect on weights. No other variables extracted from the maps affected lamb weights.

4 Discussion

Our study shows that spatial information on fodder resources throughout the year, as well as management status, can be captured in coastal heathland pastures through manual interpretation of digital aerial photographs. However, mapping heterogeneous vegetation on a fine scale entails challenges; our maps have relatively low accuracy, especially the heather classes. Wardley et al. (1987) also showed that heathland vegetation types, comparable to ours, are separable based on spectral reflectances, but as in our study, found a high degree of confusion between heather stages. Using a small MMU leads to abundant location errors because borders appear frequently. Powell et. al (2004) found that temporal changes accounted for 2.4 per cent of their errors in maps of the Brazilian Amazon. The higher change errors we found are probably related to the more dynamic system we work in, where patches may change both due to burning

Table 2: Map accuracy (%). OA=overall accuracy, CE=change errors, LE=location errors and IE=interpretation error.

OA	CE	LE	IE
60	15	13	12
61	3	15	21
77	0	16	17
64	6	14	16
59	0	14	27
59	0	11	30
54	0	24	22
67	3	18	12
59	0	9	32
62	6	15	17

and succession (Kaland 1974). In a methodologically different study, but set in similar semi-natural heathlands in France, Csaplovics (1992) used similar thematic resolution and gained an overall accuracy of 87.6 per cent for supervised maximum likelihood classification of SPOT images. However, slightly larger grid sizes were used in this study, and it is not clear whether their ground data included samples near borders, as in our study. Ecological boundaries, or the division of continuously varying properties into discrete classes, may also be a source of errors in our maps. The positive relationship between animal health and grass areas shows that despite low accuracy, the maps contain information that is relevant to sheep health. The analysis of sheep health is concerned with relative proportions of vegetation, and we assume that the relative proportions are correct even if some points are mislocated. The errors that are caused by misinterpretation (excluding change and location errors) are acceptable.

The response variable tested here was lamb weights obtained over the summer, and it is therefore not surprising that the amount of summer pasture, reflected by percentage of grass and pioneer vegetation, comes out as the significant explanatory variable. Yet, we cannot exclude that summer conditions are more important than other seasons for overwintering ungulates, as has been found by others (Weladji et al. 2003), because resources must be built up during summer to sustain the animals during winter. In order to find out more about the role of other vegetation types during the rest of the season, we needed to weigh the animals also during winter. We will relate these data to our pasture maps to find out if for example heather areas are more important during winter, as well as to get a picture of health status among the stocks during the year.

In order to learn more about grazing preferences of Old Norse sheep, we will overlay GPS data from sheep with our pasture maps. This information will be valuable; little is known about sheep preferences in winter, since overwintering is not common. Many assumptions about diet and use of landscapes by Old Norse sheep are based on studies of other breeds in a different management scheme: animals with less natural behaviour and weaker herd instincts. For the GPS study results to be reliable, we need accurate maps, and the current accuracy may not be sufficient. The study will be carried out on one single locality, and we will update our pasture map on this site to raise its accuracy. Other important further work is to link data we have collected in other parts of the project to our maps, including data on internal parasites through faecal samples, on nutrient contents of plants, and on nutrient content of blood levels in the sheep stocks.

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ABOLITION OF SET-ASIDE SCHEMES AND ITS IMPACT ON HABITAT STRUCTURE IN DENMARK FROM 2007 - 2008

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Abstract

Agriculture accounts for 65% of the Danish land area. Habitats for wild species are characterized by small patches, surrounded by intensive agriculture. Due to extensive management, set-aside land can if located close to habitats, improve habitat structure in terms of patch size and connectivity. In 2008 set-aside schemes were abolished, leading to a decline in the area of set-aside land from 6% of all agricultural land in 2007 to 3% in 2008. We developed an indicator aiming to measure the effect of the reduced area of set-aside land on habitat structure. The indicator combines distance to habitats, potential corridors between habitats and area percentage of set-aside land. Analyses show that the halving of the area of set-aside land has led to a 55% reduction of the effect of set-aside land on habitat structure.

1 Introduction

The Danish landscape is dominated by intensively cultivated land. Habitats for wild species are mainly characterised by small, spatially isolated patches within a matrix of agricultural land. Too small habitat patches and spatial isolation of habitats has been recognized a major pressure on biological diversity in Denmark (OECD 2007). Due to extensive or no agricultural management, set-aside land can, if located close to existing habitats, increase the size of habitat patches and connectivity between habitats. In order to limit overproduction in agriculture, in the early 1990ies, set-aside schemes, financially supporting the conversion of land in rotation into set-aside land, were introduced. As a consequence, during the last decade, approx. 6 % of all agricultural land has been set aside. As a response to rising prices for agricultural products, in the beginning of 2008, set-aside schemes were abolished. In Denmark, about one half of all set-aside land was re-cultivated and the area of set-aside land was reduced to 3% of all agricultural land in 2008. In spite of a considerable attention to the possible negative environmental impacts including reduced habitat sizes and connectivity between habitats, re-cultivation of set-aside land was not officially regulated. The main argument against regulation was that re-cultivation would primarily occur on highly productive land, while set-aside land, located on marginal land close to natural habitats, would typically not be re-cultivated.

Particularly in intensively cultivated areas, empirical research has shown that habitats spatial structure, in terms of habitat size and spatial connectivity between habitats, is of major importance to biological diversity (Olff & Ritchie 2002). Spatial indicators (also termed landscape metrics) are widely used as a tool to describe impacts of the spatial characteristics of land use and land-use changes on ecological processes (Billeter et al. 2008; Levin et al. 2008).

2 Material and methods

In order to investigate how the re-cultivation of set-aside land in 2008 has impacted on habitats spatial structure, we developed a simple indicator. The indicator combines distance to habitat patches, potential corridors between habitats and the area percentage of set-aside land. The method for the calculation of the indicator is described in Figure 1. Analyses were performed in a raster environment with a cell-size of 25x25 meters. In the first step (Figure 1 a), for each cell the distance to habitats was calculated. In order to include barriers for species dispersal (larger roads and built up areas) a cost surface was applied, where the cost for barriers was set to infinite. Distances were indexed from 0 to 100. Cells located next to a habitat were assigned the value 100, while cells at a cost distance beyond 500 meters were assigned the value 0. In the next step each cell was attributed a value describing whether the cell is located within or outside a potential corridor between habitat patches. A potential corridor was defined as a zone connecting at least two habitat patches. Cells within the potential corridor must be located no more than 500 meters from at least two habitat patches. As for the distance measure, potential corridors are based on a cost distance surface in order to account for barriers for species dispersal. The cost distance and corridor measure were combined into one measure (Figure 1 b). For cells located outside potential corridors, the cost distance was subtracted the value 5. I.e. that a cell located next to a habitat patch but not within a potential corridor was attributed the value 95, compared to a cell next to a habitat patch and within a corridor, which would be attributed the value 100.

Danish agricultural registers contain information on the agricultural land use at field scale. However, the registers do not contain information on the precise location of the single fields but only information about within which field block the field is located. Field blocks are aggregates of multiple fields and have typically a size of 0.5 hectares. Thus, for each field block it is possible to calculate the area per-

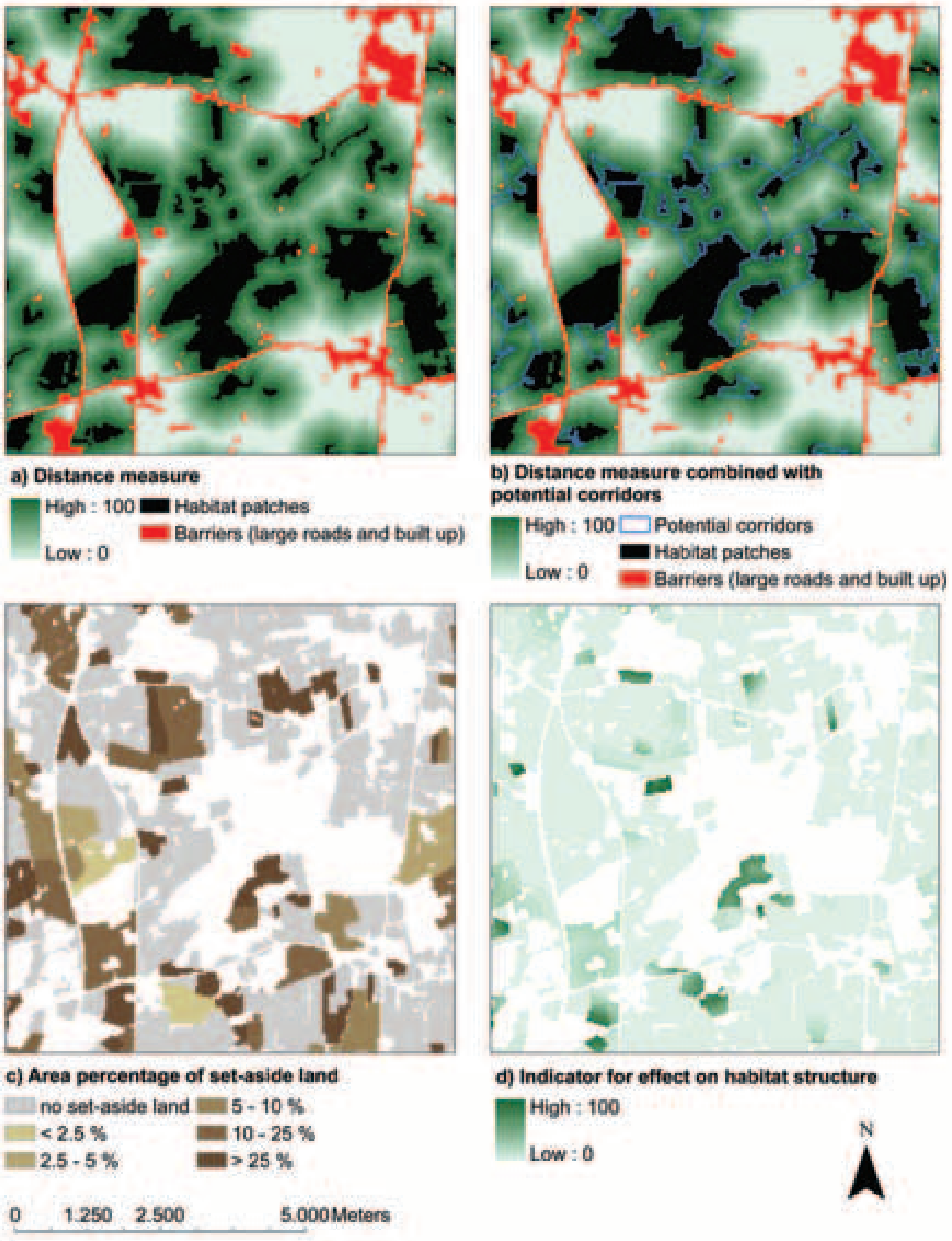

Figure 1: Illustration of method for calculation of indicator for the effect of set-aside land on habitat structure. a: measure for cost distance from habitat patches; b: cost distance combined with potential corridors; c: area percentage of set aside land; d: Indicator for effect on habitat structure (combined cost distance and corridor measure, multiplied with area percentage of set-aside land).

centage of set-aside land. Therefore, in the third step, for each cell, the area percentage of set-aside land was determined (Figure 1 c). In the final step (Figure 1 d), the indicator for habitat connectivity was calculated. For each cell, the combined measure for distance from habitat patches and for potential corridors was multiplied with the percentage of set-aside land. The resulting indicator was scaled from 0 – 100. The indicator value increases with an increasing area percentage of set-aside land, decreasing distance from habitats and if located within a potential corridor. Cells, which are located next to a habitat, within a potential corridor and have an area percentage of set-aside land of 100, will have an indicator value of 100. In contrast, cells with no set-aside land or cells which area located beyond 500 meters from habitats will have an indicator value of 0.

3 Results

Analyses showed, that for the whole country, the indicator for the effect of set-aside land on habitat structure was reduced from 2.02 in 2007 to 0.91 in 2008. I.e. a halving of the area of set aside land led to a 55 % reduction in the effect on habitat structure. In order to elucidate regional differences, results were aggregated to 10x10 kilometre squares (Figure 2). The figure shows a relatively clear regional pattern, where the reduction of the effect of set aside land on habitat connectivity from 2007 to 2008 was most pronounced in the central and western part of the Jutland peninsular. This pattern is a consequence of the largest reduction in set-aside land having occurred in these areas.

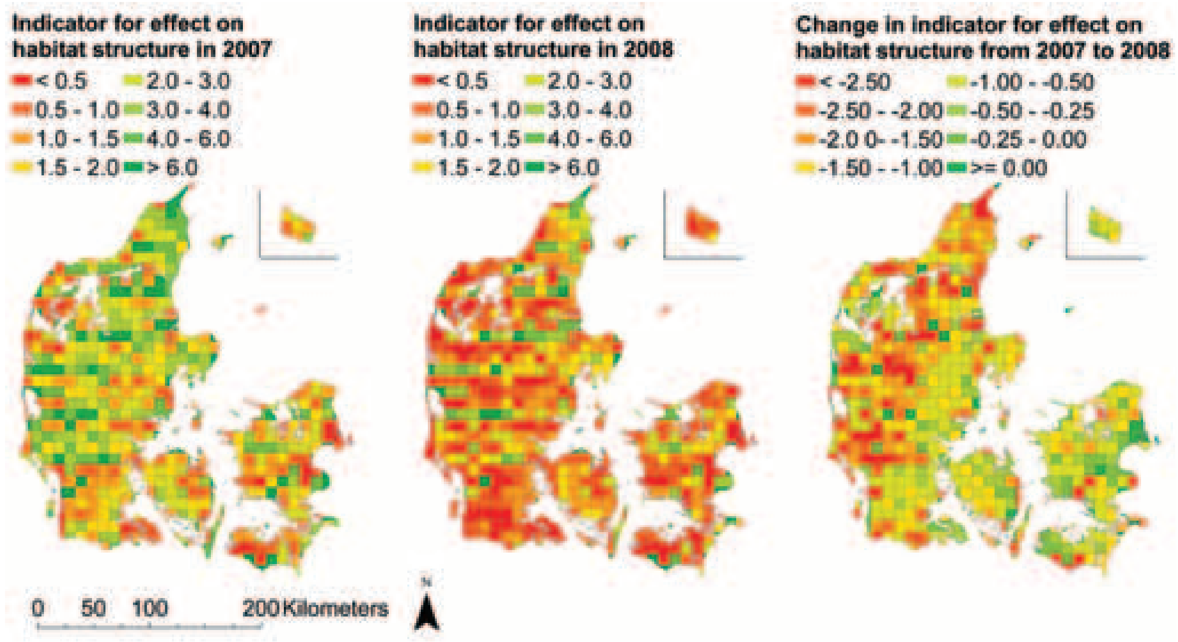

Figure 2: Results of calculation of indicator for the effect of set-aside land on habitat structure. Values are aggregated to 10x10 km squares.

4 Discussion

Results indicate, that re-cultivation of the half of all set-aside land in Denmark in 2008 has had a profound negative impact on habitat structure. The main argument against regulation of re-cultivation of set-aside land was that re-cultivation would primarily occur on highly productive land at a long distance from habitats, while set-aside land, located on marginal land close to natural habitats, would typically not be re-cultivated. The results from this study clearly do not support this argument.

The elaborated indicator for the effect of set-aside land on habitat structure is only based on information on cost distance to habitats and area percentage of set-aside land. In spite of the importance of habitat size and connectivity, suitability of set-aside land to improve habitat functions depends on a number of other parameters, such as physical-geographical conditions (e.g. soil substrate and humidity) and land use history (e.g. the number of years an area has been set aside). In the future, such parameters could be included in order to strengthen the indicator.

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INTERPRETATION OF HIGH RESOLUTION DIGITAL AERIAL PHOTOGRAPHY IN A DIGITAL 3D ENVIRONMENT TO MAP VEGETATION COMMUNITIES FROM A PRE-EXISTING CLASSIFICATION

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Abstract

This project served as a trial of approaches required to complete regional vegetation mapping across large areas through aerial photo interpretation (API) of newly available high resolution digital aerial photography (Leica ADS-40) within a digital 3D environment (Stereo Analyst for ArcGIS, viewed with Planar screens).

The project showed that, at very least in areas west of the New South Wales (NSW) Great Dividing Range, the ADS-40 imagery being flown for most of NSW, is more than adequate to map out the NSW VCA (official Biometric) vegetation community types, which are equivalent to those used in the biodiversity assessment tools authorised by the NSW Government, ie the Biometric Tool used in the Property Vegetation Plan (PVP) Developer. It was shown that this could be done directly from API alone, in the presence of an existing (a priori) classification, without the need for any additional floristic data gathering or analysis. 31 VCA types were mapped down to a minimum size of 0.5 ha and minimum woody density of 5 % crown cover. This approach provided significant gains in accuracy, and savings in terms of time and costs, when compared to using lower resolution wet film photography for API followed by a second stage for data capture.

The important outcome of this project was that the Biometric plant community classification, used by Catchment Management Authorities (CMAs) in the NSW PVP Tool, can now have a spatial representation relatively quickly, accurately and cost effectively. This was needed for creation of a CAR (Comprehensive, Adequate and Representative) reserve system and NRM decision making.

1 Introduction

This report details a novel approach to vegetation mapping for land use planning and natural resource management (NRM) decisions using high resolution digital aerial photography in a digital 3D environment. The aim was to produce a vegetation map in the NSW South West Slopes of the plant community types used in the NSW Vegetation Classification & Assessment (VCA) (Benson 2008). This was to be at a level defined as Product Class 3 (new API with no new full floristic plots) and to Classification Level D (plant community types), consistent with the draft NSW Native Vegetation Mapping Strategy (DECC 2009).

The project also trialled approaches to complete vegetation mapping through aerial photo interpretation (API) of the newly available high (50 cm) resolution digital aerial photography collected using a second-generation airborne digital camera developed by Leica Geo-Systems (ADS-40). The ADS-40 photography was interpreted in a digital 3D environment using Stereo Analyst for ArcGIS 9.2, viewed with 20” Planar screens in the presence of an existing (a priori) classification, without the need for any additional floristic data gathering or analysis. An approach that was previously difficult, to impossible, using available 1: 50,000 scale wet film photography.

The NSW VCA (Benson 2006) plant community classification used in the Biometric Tool (Gibbons et al. 2008) previously had no spatial representation, which limited its practical application to NRM tasks. It was hoped this approach could develop a spatial representation relatively quickly and cost effectively. Such a map could address existing shortfalls in current vegetation mapping extent and provide adequate support for a variety of NRM and Land Use decisions such as the creation of a CAR (Comprehensive, Adequate and Representative) reserve system.

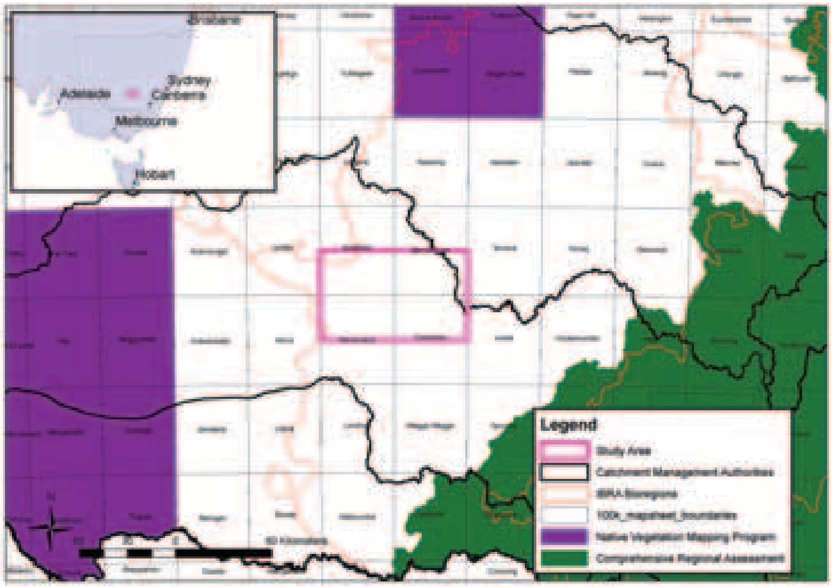

Figure 1: The study site encompassing adjoining sections of the Ardlethan, Barmedman, Narrandera and Coolamon 1: 100,000 scale mapsheets.

The precise location of the study area was determined on the basis of availability of the ADS-40 imagery, and from discussions between officers from the Federal Dept of Environment, Heritage & the Arts (DEWHA) and the NSW Dept of Environment & Climate Change (DECC). The study area totalled 509,000 ha (approx.) and consisted predominantly (95.4 %) of freehold land (485,608 ha), with some smaller areas of State Forest (6,120 ha), State Forest Timber Reserve (969 ha), Crown Reserve (11,188 ha), National Parks & Wildlife Service estate (5115 ha).

2 Methodology

All pre-existing vegetation data layers were examined. The absence of useful existing data provided the project with a clean slate on which to test the use of ADS-40 imagery for identifying species and delineating vegetation communities. Aerial photo interpretation (API) was undertaken using the newly available high resolution (50 cm) digital aerial photography collected using a second-generation airborne digital camera Airborne Digital Sensor (ADS-40) (Leica Geosystems 2007). The photography was commissioned by NSW Department of Lands from July 2007 to replace their existing film-based configuration.

In April and May 2008, a mapping team of four experienced API mappers worked using 3D digital workstations. API was done in the 'traditional' way where mappers used their experiential judgement to draw polygons based on patterns in the imagery, position in the landscape, as well as shape, colour and texture of tree crowns (DUAP 2000). Colour (RGB) imagery was used. Unlike traditional API, the mappers used high resolution digital imagery in combination with 3D viewing software (Stereo Analyst for ArcGIS 9.2) and Planar screens, which allowed the digital imagery to be seen in high resolution 3D and for the interpreted 'line work' to be drawn directly on screen and digitised as it was generated (as 'polygons' in an ArcGIS 3D shapefile) and attributed immediately by the actual mapper. Use of the 3D digital technology enabled mappers to view the high resolution photography at a number of scales using the 'zoom' function. Mappers were also able to view existing GIS layers in the 3D window, such as previous vegetation mapping, soil mapping, plot data to assist interpretation. The Planar screen workstations, are shown in Figure 2.

API mappers used the NSW VCA (Benson 2008) vegetation classification as the primary attribute field for each polygon. Each polygon (minimum size 0.5 ha and density 5 % ccp) was attributed with a VCA value that best fitted the estimate of which dominant species were observed in the imagery. The code string (attribute fields) was as follows:

FID / Shape / Veg Poly ID / 100k Map / Aggregate Code / VCA Code / Dom Spp (up to 3 in order) / Total Woody % Cover / Tallest Stratum % Cover / Ground Cover / Growth Form / Land Form / Reliability Code / Photo Date / Digitising Date / Digitiser / Notes / Photo (Strip) No. / Hectares.

In April 2008, prior to beginning mapping, the team of 4 contracted API vegetation mapping experts initially spent a week in the field with two botanists experienced in the local area. Fieldwork accounted for approximately 20–30 % of project time. Field notes for office referral were recorded onto 1: 25,000 scale A0 size colour printouts of the ADS-40 2D orthophoto mosaic.

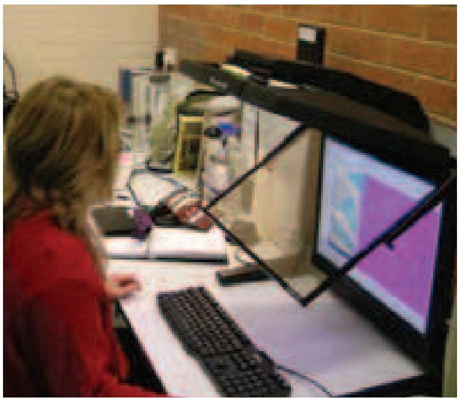

Figure 2: Interpreters at 3D workstations.

All GIS editing and processing was done using ESRI's ArcGIS 9.2. The four 3D shapefiles from the four 1: 50,000 mapsheets were all converted into 2D shapefiles, using the function for this in Stereo Analyst, and then unioned into a single shapefile layer. The unioned layer was further edited by the project manager, who was closely familiar with the mapping project and possessed API skills, to undertake edge matching between sheets. Any illogical or illegal codes and to correct shapefile topology errors (such as slithers and unattached 3D vertices), as a result of the 'flattening out' of 3D shapefiles into 2D shapefiles, were amended. Editing was conducted with the ADS-40 imagery 2D orthophoto mosaic as a backdrop.

A blind field validation assessment was done by independent consultants Eco-Logical Australia (2009). Random stratified plots were generated within woody vegetated areas mapped. The key information, recorded at each plot on a proforma, was as follows: 3 dominant species (in each of three strata, if present); NSW VCA type; best alternative VCA type (if needed); second alternative VCA type (if needed) and Landform. Four classes of correctness were used, in accordance with the draft NSW Vegetation Mapping Standard (DECC 2008), (Gopal & Woodcock 1994).

3 Results

The mapping produced a single 2D digital vegetation map of NSW VCA vegetation community types. Each GIS polygon was mapped to a minimum polygon size of 0.5 hectares and 5 % woody crown cover and the shapefile was attributed with a unique set of attributes, in accordance with the code string. Thirty-one NSWVCA vegetation community types were mapped throughout the study area. A total of 6875 polygons (75,610 ha) of native vegetation were delineated.

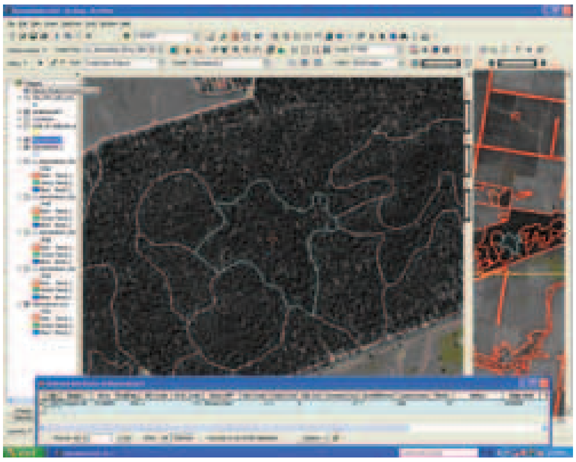

Figure 3: Screenshot of Stereo Analyst interface. Stereo window (centre) at 1:7,000 scale and ArcMap window (right) at 1:40,000 scale. The same polygon is selected in each window and its record in the attribute table

The overall map accuracy level awarded was 82 % (Eco-Logical Australia 2009). This comprised of the two higher levels of accuracy. Level 1) being 49 % for plots having an exact VCA match and level 2) being 33 % for plots which were so floristically and structurally similar as to be essentially deemed to be correct. 13 % were at level 3) and 5 % were at level 4) accuracy.

4 Discussion

This project was the first vegetation mapping project in Australia to use digital 3D interpretation of ADS-40 imagery. It was found that the use of ADS-40 imagery in 3D offered a number of advantages over more traditional API.

- The unprecedented image resolution of the imagery enabled more floristically, and spatially, accurate delineation of vegetation types.
- The API line-work is digitised and attributed as it is created. By digitising polygons over the 3D image in the Stereo Window, linework was simultaneously drawn in both windows.
- Existing spatial data, whether existing vegetation data or data on soils or geology, can be viewed simultaneously, in 3D, in the ArcGIS/Stereo Analyst environment.
- Numbers of interpreters are able to view the 3D image at any one time, establishing consultative processes between mappers that allows for greater consistency.

The VCA units seemed logical and representative of the regional floristic biota. The VCA units were the right part of the classification hierarchy to be mapped, as they were realistic map units that had very high useability potential through CMA use of the NSW Native Vegetation Assessment Tool (formerly PVP Tool) (Gibbons et al. 2008).

The mapping was shown, through the field validation and accuracy assessment, to have an overall accuracy level of 82 % (ELA 2009). Eco-Logical Australia (ELA 2009) stated in their report to DECC that “This result suggests that the approach used to map vegetation in the Narrandera region may have wider application in NSW”.

5. Conclusion

The ADS-40 imagery being flown for most of NSW, is more than adequate to map out the official Biometric NSW VCA (Benson 2006) vegetation community types. This was a cost effective and accurate method of spatialising and operationalising the NSW VCA classification over unmapped areas of fragmented and depleted landscapes, such as the SW Slopes of NSW. Given that the NSW VCA is essentially a compendium of pre-existing vegetation plot data, this could be done directly from API alone, in the presence of this existing (a priori) classification, without the need for, and high expense of, any additional floristic data gathering or statistical analysis.

A major benefit of this mapping approach is that the Biometric classification used by State Government for regulation of Native Vegetation ie. CMAs in the PVP Tool (Gibbons et al. 2008) and NRM decisions, can now have an accurate spatial representation. The approach also provided significant savings in terms of time and costs when compared to the traditional approach of using lower resolution wet film photography for API followed by second stage data capture.

6. Recommendations

- Expansion and Roll-Out of Methodology into a wider NSW Native Vegetation Mapping Program.
- Trial project combining automated image recognition as a first stage followed by digital 3D API as a second stage, which could potentially speed up and cheapen this mapping process.
- Possible trial of using colour infra-red (CIR) imagery as is done in Sweden (Ihse 1978).

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LARGE-SCALE MAPPING OF ACTUAL VEGETATION IN HETEROGENIC LANDSCAPE CONDITIONS (NW LADOGA REGION, RUSSIA)

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Abstract

Investigations were carried out in the north-western Ladoga region, the southern part of the Baltic Crystalline Shield. The landscape of this region is characterized by alternation of granite ridges (selgas) and depressions that are occupied by bogs, lake terraces and lakes. Boreal coniferous forests and mires are typical vegetation. The purpose of this investigation was to explore and map the actual vegetation, but also to study the phytocoenotic diversity and to estimate present-day changes of plant cover.

1 Introduction

Ladoga Lake is the largest lake in Europe (the area is 17870 km^2, the volume of water – 838 km^3, the average/maximum depths – 47/230 m). The lake is situated between two large geological structures: the Baltic crystalline Shield and the Russian Platform. The tectonic uplift of northern Ladoga areas occurs with a speed of some millimeters per year, opposite the southern Ladoga coasts annually subside (Isachenko & Reznikov 1996).

The climate of the Ladoga region is influenced by some important geographical factors: frequent fronts of the Baltic, White and Barents seas, and prevalence of intensive cyclonic activity during the whole year. The Ladoga Lake influences on the adjacent territories making the climate milder. The Karelian coastal areas of Ladoga are characterized by mild winter, and longer vegetative and frostless periods (Ladoga Lake 2000). According to Nazarova (2006), the annual temperature has increased from 1.1ºC to 1.3º C in 50 years (1951–2000) in the Northern Ladoga region.

The study area is located in the southern part of the Baltic Crystalline Shield. The specific features of this territory are various rocks (granite and granodiarite, limnetic clay, pet) and compound relief (tops, slopes and foots of selgas, limnetic terraces and depressions). The limnetic terraces of Ladoga region are the former bottoms of the Baltic glacial lake [10300], Antzil lake [8500] and ancient Ladoga [dated 2800–3700 years ago] (Koshechkin & Subetto 2002). The most fertile lands, such as terraces and bogs, were actively used for agriculture (before the 1940ies by Finns, later on – by Russians). Sod-gley soils with thick (up to 25 cm) structured humus horizon were developed on the cultivated terraces (Gorbovskaya et al. 1995). According to radiocarbon data the bogs began to form about 8700 years ago (Arslanov et al. 1995). The NW Ladoga region is situated in the taiga belt. Spruce, pine and small-leaved forests prevail in the study area. Meadows and bogs have few localities within the study area.

The purposes of these investigations were: to explore the phytocoenotic diversity, to create the actual vegetation map, and to assess the present-day changes of plant cover. The new regional complex nature reserve is planned to be establish in the NW Ladoga region, therefore the actual vegetation map and the database of relevés are important for carrying out future environmental monitoring.

2 Materials and Methods

The research and vegetation mapping of the north-western Ladoga region were carried out from the Geography Research field station of St.-Petersburg State University. This station is located by the small Lake Suuri (61° 7'N, 29°55'E). The field investigations were carried out in 1998–2005 (1998 –

reconnoitering work, 2002–2005 – mapping). Vegetation studies were performed according to the Russian traditional ecological-phytocoenotic (i.e. dominant) approach (Galanina & Heikkillä 2007). Almost 400 relevés were made and than they were grouped according to the types of vegetation (forests, shrubs, bogs, meadows), organized into tables and rearranged on the basis of the dominant species in the tree layer, bush layer and field- and bottom layer. The map of actual vegetation (1: 25,000) was compiled using GIS-programs (GeoDraw, GeoGraph), performed at the GIS Research Centre of the Institute of Geography of the Russian Academy of Sciences (http: //geocnt.geonet.ru/en/).

Methodology of digital and field vegetation mapping:

1. Analysis of aerial photographs, topographical and landscape maps. Layers of aerial photos and maps were overlaid in the program GeoDraw. The black-and-white (1953) and color (2003) aerial photos, Finnish (1930–1940) and Russian (1980) topographic maps were used.
2. Definition of preliminary borders of vegetation types. The digital image of the preliminary map polygons was made. The data on outlines of preliminary map carried tentatively character, polygons were subdivided on the forests (spruce, pine or small-leaved), meadows, bogs (pine or open), lakes, settlements, roads, etc. Also, the information about ecological site conditions for preliminary map polygons was extracted from topographical and landscape maps.
3. Field inventory of biodiversity (trees, shrubs, dwarf shrubs, herbs, mosses and lichens) in each polygon of the preliminary map. The results of aerial photos interpretation were used for mapping as well as field data on vertical and horizontal structure of plant cover.
4. Linking the map to data-base of vegetation descriptions. The database contains information on landscape type, texture of soils, vegetation type and species composition, coverage of layers and anthropogenic impacts for each map contour.
5. Detection between primary and secondary communities. Why did we determine them? Primary communities are represented by old growth forest types. They need to be protected. The secondary communities are represented by serial succession stages: secondary permanent and short-time communities.
6. Indication at the map's legend of special series of vegetation dynamic after anthropogenic impacts (fires, forest felling, drainage of bogs, abandoned meadows and arable land with forest regeneration). The short-time communities have a number with apostrophe, for example, 7' – Spruce herbaceous-ferny-sphagnous open forests (after selective felling). Also the most disturbed communities are shown by bright colors and hatching.

3 Results

Due to the heterogenic ecological conditions of NW Ladoga region the flora and vegetation are very diverse. 280 vascular plants (16 trees, 15 shrubs, 19 dwarf shrubs and 230 herb species), 64 moss species (15 sphagnous, 4 liverwort) and 12 lichen species were recorded from the study area. According to the «Red Data Book of nature of Leningrad region» (1999) protected objects of Nature regional reserve «Kyznechnoe» are the rocky complexes, sites of migratory birds and rare plant species such as *Woodsia ilvensis* (L.) R. Br., *Hierochloe australis* (Schrad.) Roem. Et Schult., *Pulsatilla vernalis* (L). Mill. During field observations some rare species of the Leningrad region (Red Data Book 2000) were found on the mapping key-plot. They are *Pulsatilla pratensis* (L.) Mill., *Nymphaea tetragona* Georgi, *Rubus arcticus* L.; green moss *Racomitrium lanuginosum* (Hedw.) Brid. and liverwort *Anastrophyllum saxicola* (Schrad.) R.M.Schust.

The created original vegetation map indicates the state of vegetation in the year of 2005 (Figure 1). Contour colors of the vegetation map legend correspond to the Russian school of vegetation mapping: violet – spruce forests, brown – pine forests, green – small-leaved forests, blue – bogs, and light green – meadows. Moisture gradients of ecotopes are shown by increasing color value (from wet to dry communities). Light contours are wet communities; dark ones are dry communities.

52 association groups and 56 associations and sub-associations were revealed (Figure 1). In the legend the association groups are marked by number (1, 2, …,15); association and sub-association – number with Russian letter (1a, 3a, …, 13a). 13 primary, 26 secondary permanent and 5 secondary short-timed association groups were distinguished. The highly disturbed vegetation communities are shown as a separate group in map's legend. The vegetation diversity is represented by 16

mosaic groups of plant communities. Regular alternation of plant communities is shown as complexes or combinations in the map and they are separated in the map's legend (for example, rock complex – 11*, combination of small-leaved gladue (*Aegopodium podagraria*) and macrophyllous meadows – 30a*, combination of multiple-aged reforestation stages after forest felling – 45*, etc.). The total area mapped is about 35 km^2. The forests (67 %) are the dominant vegetation type (Figure 2). The pine (30 %) and spruce (13 %) forests are the main forest types; small-leaved forests consist of birch, aspen and grey alder trees, infrequently mountain ash (*Sorbus aucuparia*) and willows (*Salix caprea,*

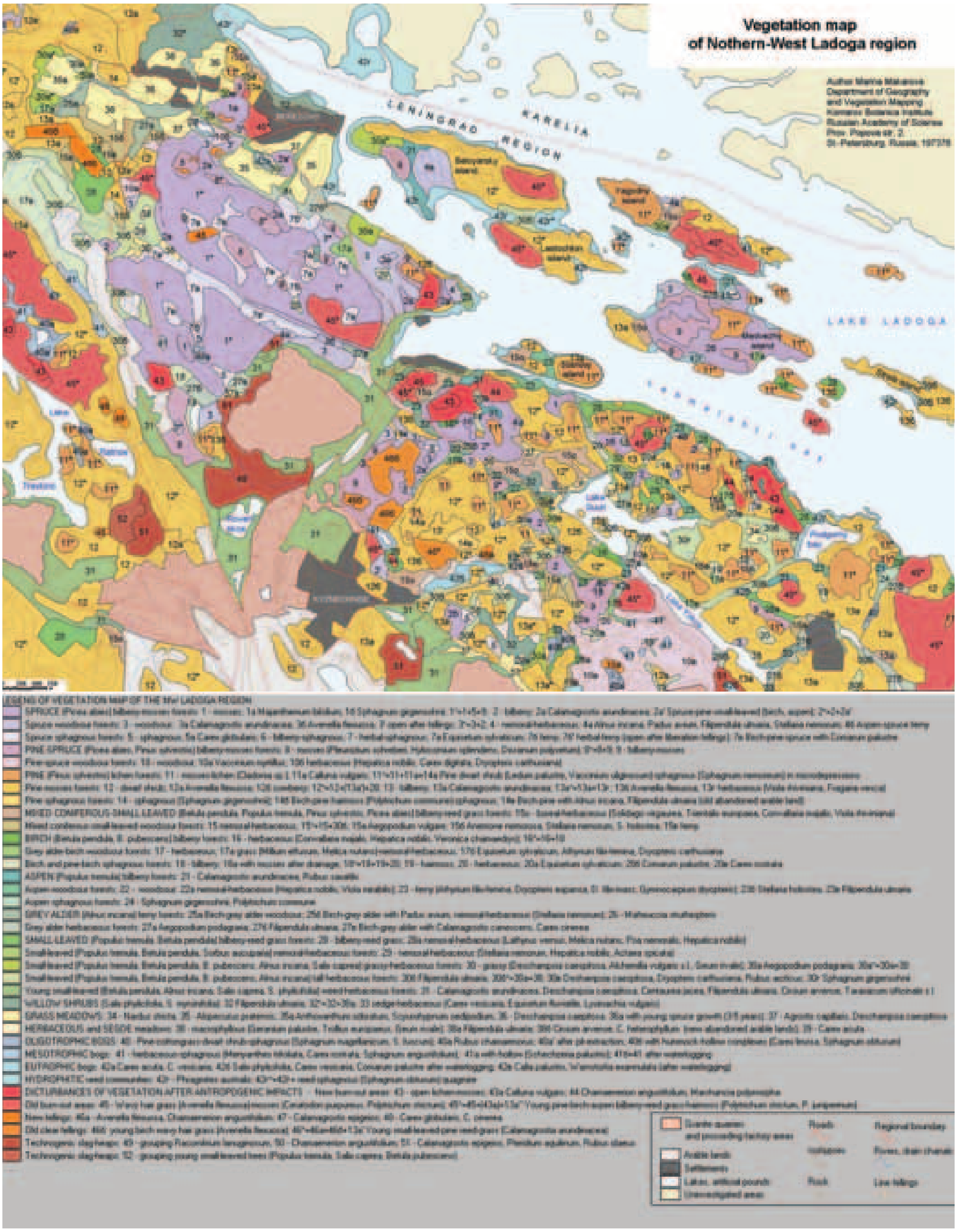

Figure 1: Actual vegetation map and map legend of the NW Ladoga region.

S. pentandra). Willow shrubs, meadows and bogs have limited distribution. The lands that are in use (settlements, arable lands and granite extractions) occupy approximately 20 % of study area.

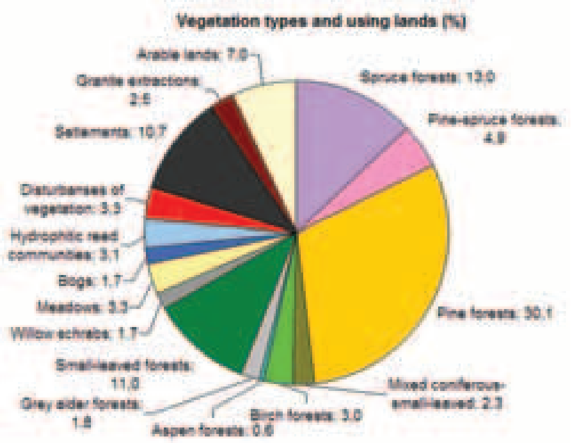

Figure 2: Correlation between vegetation types and lands in use (%).

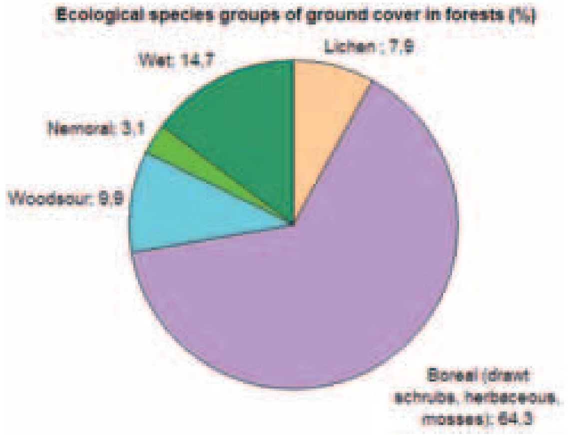

Figure 3: Correlation between ecological groups of ground layer in forest types (%).

4 Discussion

There are different opinions on the delimitation of the middle and southern taiga subzones in the NW Ladoga region. Russian literature sources consider the study area belonging to the middle taiga (Nitsenko 1958; Aleksandrova *et al.* 1989, http: // mfd.cepl.rssi.ru/flora/middle_taiga.htm). However, according to the Finnish and some Russian scientists it belongs to the southern taiga (Ahti, Hämet-Ahti, Jalas 1968; Hämet-Ahti 1988; Yurkovskaja, Pajanskaja-Gvozdeva 1993). My work shows that this territory lies in the transitional zone between the southern and middle taiga. The total area of the actual nemoral forests is 13 %. The area of potential nemoral forests will increase in future (Figure 1, 3).

The vegetation in heterogenic landscape conditions can be reflected on the map as community complexes, combinations or ecological series. The rock (selga top) complexes were shown at the original large-scale vegetation map (legend number 11*) in a scale 1: 25,000. The rock complexes are composed of open pine mosses-lichen, heather forests in convexities and dwarf shrub-sphagnous in microdepressions. Also, the map demonstrates the vegetation of slopes (spruce mosses, woodsour, nemoral-herbaceous and mix birch-aspen-pine grassy-bilberry, nemoral-herbaceous forests) and foots (spruce and aspen ferny forests and young grey alder honeysweet forests). In a smaller scale, for example 1: 50,000, the different forest types of selga hills will be shown on the map as one *lithogenic* complex of vegetation including the plant communities of selga tops, slopes and foots. The large bogs and meadows on lake terraces will be indicated on the map as separate contours, but small ones will disappear due to a generalization process.

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PLANNING CHANGES – OR CHANGING THE PLANS?

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1 Introduction

Municipal land use planning is intended to ensure that the landscape is managed sustainably. This planning is guided by a number of laws, rules and regulations, administered at the national and regional level. Examples in Norway are the Land Act aiming to protect farmland, and a national directive protecting the shoreline from development. However, the local municipality has to provide infrastructure, housing, workplaces and recreation environments for taxpayers, as well as manage natural and cultural heritage. This can lead to conflicts, particularly when different interests may require planning on different temporal and spatial scales.

Acknowledging the challenges involved in land use planning, a National audit was conducted in 2006–2007 (OAG 2007). This audit concluded that «…the state and development of land in Norway in several respects do not safeguard values and principles emphasised by Parliament to ensure a sustainable use of land» (OAG 2007, p. 16). The investigation found that management of land did not comply with sustainability aims and that land use planning lacked overall long term perspective. Further more, although most land use development was in accordance with municipal plans, these were often in conflict with national plans.

In this paper we report some key findings from a study that quantified actual land use change over a period of almost 20 years, with a particular focus on agricultural land. We discuss this in the context of national and regional directives on land use change.

2 Study area and methods

The study area comprised five municipalities in South-Eastern Norway (Figure 1). The municipalities represent a transect from the Oslofjord coast, where there is relatively rapid population growth and therefore pressure to build and develop land, to inland municipalities where this is less of a challenge. The municipalities differed in size (from Moss at 58 km^2 to Våler at 239 km^2) and population density (from 510 people per km^2 in Moss, to 19 people per km^2 in Våler).

Land use change was quantified based on two sets of mapdata, reflecting land use and land cover in 1984 and 2004. The historical data existed only as image files from scanned paper maps from the Economic Map Series («Økonomisk kartverk», scale 1: 5 000). The 2004 data were available in digital format («Digitalt Markslagskart»), based on an updated version of the Economic Maps (i.e. using the same mapping rules and classification system).

To enable map-based comparisons through GIS, we first created a new digital vector cover reflecting land use/cover for 1984 through «back editing» the current maps using the scanned historical data in the background. This allowed a comparable and quantifiable digital spatial analysis of two time periods, without discrepancies arising from different data sources (quality of the digitising, amount of total areas digitised, or differences arising from digitising at different scales). A series of standard GIS analyses of change over space and time were performed, intersecting several data themes, and quantifying combinations of changes.

To analyse building developments we made use of the national database of all buildings, GAB («Grunneiendommer, adresser og bygninger»). We examined shoreline development by creating a 100 m buffer zone around water and counted the number of new buildings within this zone. Similarly, we counted new buildings within areas that had been designated as areas of conservation interest.

Figure 1: Location of study area in Norway and major land uses in the five municipalities making up the study area (yellow = agriculture, green = forest, grey = built-up land, blue = water).

3 Results

Regarding national aims to preserve agricultural land, we found that the total area of agricultural land converted to other uses was relatively small, but differed between the five municipalities. In four municipalities there was a net loss of agricultural land. The greatest loss was in Rygge, with a net loss of 5.5 % of the original agricultural area. In Hobøl, by contrast, there was a small net gain of agricultural land during the 20 year period (corresponding to 0.4 % of the original agricultural area). Parcels of land converted from agricultural to other uses were generally small and were not clustered in any particular parts of the municipalities, but were scattered over the entire area.

In all of the municipalities there was an increase in the area of built-up land from 1984 to 2004. All five municipalities also experienced a net population increase during the period, from an 11 % increase in Moss to 20 % in Hobøl. Although Moss had the smallest increase in proportion to the population in 1984, this was the greatest increase in total numbers (2851 people). Moss was also the municipality that converted the highest relative proportion of agricultural land to built-up land (36 % of the agricultural land that was lost became built-up). However, this municipality also had the smallest proportion of its area under agriculture to start with (12 %), and a considerably smaller total area of agricultural land than the other municipalities (688 hectares compared with three to four thousand hectares for the others).

In general, isolated patches of agricultural land seemed to have a higher likelihood of being converted to other uses than larger tracts of agricultural land.

For the entire study area, previously forested land accounted for 75 % of all new built-up land whilst 16 % came from agriculture. Most of the agricultu-

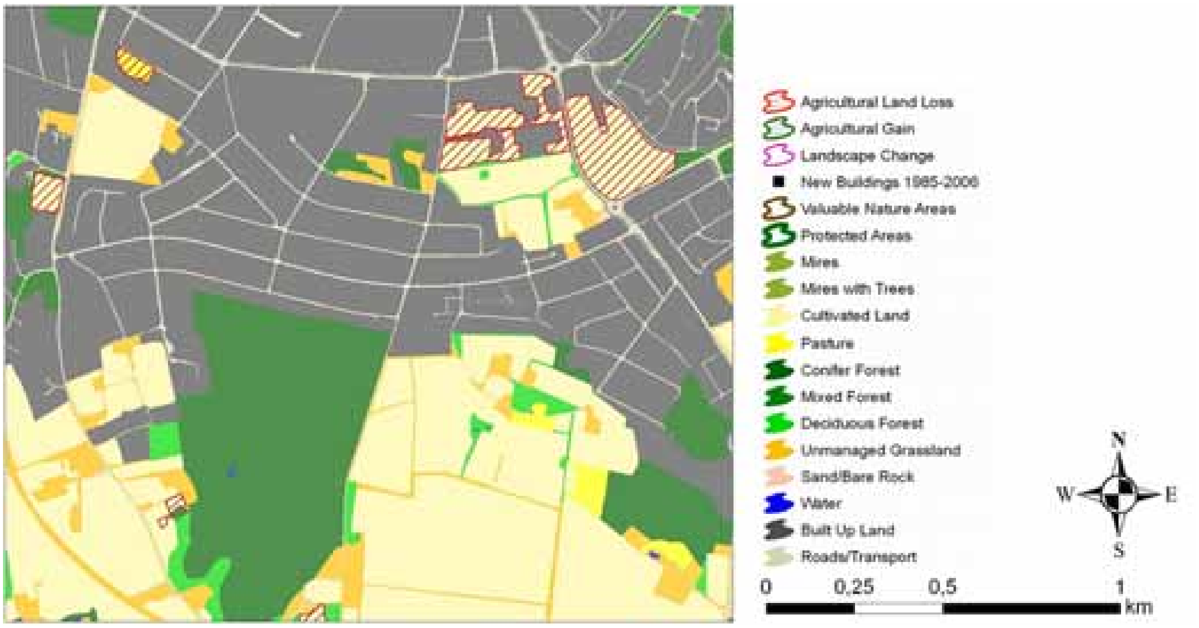

Figure 2: An example of agricultural land lost to other land uses (red hatched area). Smaller and more isolated patches of agricultural land appeared to be more at risk of conversion to other uses than larger blocks of agricultural land.

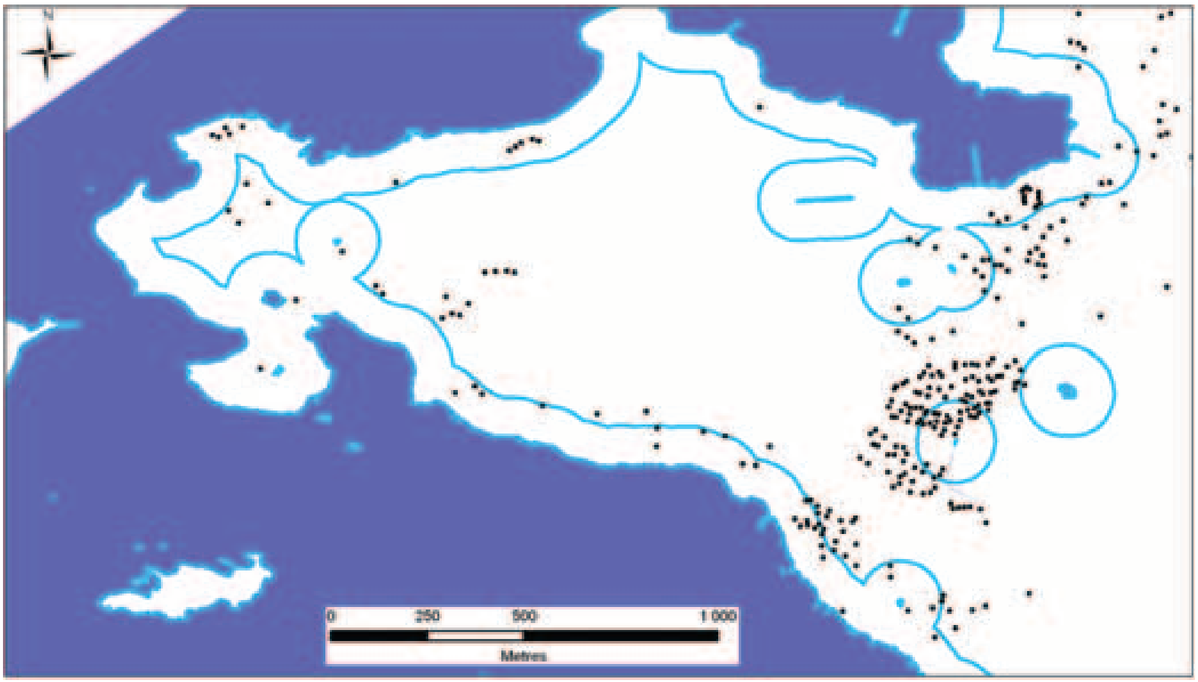

Figure 3: The inner boundary of the 100 meter buffer zone around water is shown in turquoise, with the black points showing buildings built within this shoreline zone after 1984.

ral land converted to other uses was converted to «unmanaged grassland», which may be seen as a transition category, either on the way to becoming built-up land, or in transition to forest cover. The percentage of built-up land coming from agriculture varied considerably, from 4 % in Moss to 42 % in Hobøl.

The analysis of shoreline development showed the presence 897 buildings built after 1984 within 100 meters of the shoreline. There were a total of 6375 buildings within 100 meter of the shoreline. Moss and Rygge had over 300 new buildings, Hobøl and Spydeberg around 100 and Våler less than 30.

4 Discussion

The amount of agricultural land converted to other uses was generally low in the study area. This is in line with the focus in Norway on food self-sufficiency and the importance of protecting the small proportion of land suitable for food production (Bjørkhaug & Richards 2008). Also, agricultural land represents a fairly small proportion of the total area converted to new built-up land. This can be interpreted as an indication of a relatively restrictive approach regarding building on agricultural land, and that agricultural land is not the preferred choice. However, it seemed that smaller and more isolated patches of agricultural land were most at risk of conversion. In some cases, the agricultural land was partially surrounded by built-up areas, as a result of the policy encouraging municipalities to build new houses in existing population centres, rather than allowing scattered settlement (NOU 24: 2003).

In addition to the fairly small proportions of agricultural land converted to built-up land, agricultural land is also converted to «unmanaged grassland». This may either represent a first stage in a succession following abandonment, where the land cover eventually will be forest, or it may be a transition phase to becoming built-up land. This map category can disguise trends of change when looking at maps for just two points in time. However, a longer time series of analysis would provide a better picture of the pathways of change.

A more negative aspect of change in the municipalities under study related to the appearance of new buildings in areas where restrictions apply, such as the 100 meter buffer zone along the coastline. This topic has also received a lot of attention in Norway, as there have been several cases where the coastline has been developed piece by piece over a long period of time, thereby restricting access and limiting the use of the coastline for recreation by the general public (MoE 1993).

In general in the study we found a large number of fairly small changes more or less scattered over the entire municipal area. Small changes taken individually may not seem too problematic, but if projected into the future, and taken cumulatively, they could have significant negative impacts on sustainability. We suspect the result to be a consequence of a decision-making on the scale of each independent application for dispensation instead of according to an overall plan. This is probably also a consequence of the system where politicians, being elected for a four year period tend to operate on a short term timescale. These resources need to be managed on a much longer timescale, however. To put things in perspective, one should consider that some of this land has been used for agriculture for ca. 5000 years. Also, regarding both the examples given here, it is vital to remember that the amount of new land available to transform to agricultural is very limited. Likewise, when the coastline buffer zone is converted to privately owned land, this will be very difficult to revert at some later stage, i.e. the changes are virtually irreversible.

In our perspective, the challenge for the local authorities is to decide how best to use available tools to monitor and improve the long term sustainability of local planning decisions. We suggest that currently municipal development may be shaped more by the cumulative effects of many small individual plans rather than by a single long term plan for the whole municipality. They need to ensure they indeed are taking the various interests into consideration and at the same time to assess their influence in total numbers, not just on the basis of each independent event.

Acknowledgements

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A EUROPEAN WIDE INDICATOR FOR THE STATE AND DIVERSITY OF THE RURAL-AGRARIAN LANDSCAPE

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Abstract

An operational indicator for monitoring the impact of the Common Agricultural Policy on landscape has to cope with several challenges: being sufficiently exhaustive to represent the complex interrelation of elements that compose a landscape but at the same time sufficiently simple to convey effective messages to policy makers; be based on (and therefore limited by) existing data at EU level in order to be fully operational; capture the variability of European agricultural landscapes; be sufficiently sensitive to identify changes in landscapes when used in a monitoring frame.

The first proposal for a EU landscape state and diversity indicator, set up to answer the policy request contained in the COM(2006)508 «Development of agri-environmental indicators for monitoring the integration of environmental concerns into the common agricultural policy», tries to answer all this and represents the first attempt to define a comprehensive indicator targeted at the rural landscape.

1 Introduction

In the legislative frame of the European Union there is no specific legislation concerning management and preservation of landscapes, which is under the responsibility of Member States. EU policies, though, deeply affect landscapes, and monitoring activities are necessary to assess the impact of such policies on landscapes and on the environment in general. This is particularly true in the frame of the Common Agricultural Policy (CAP), agricultural activities, in fact, affect 47 % of the EU-27 surface and such share increases to 78 % if forestry is included. Therefore decisions taken in the frame of the CAP are likely to impact on a consistent part of the EU surface. For this reason, and following the process started at the European Council at Cardiff in June 1998, that invited all relevant formations of the Council to establish their own strategies for giving effect to environmental integration and sustainable development within their respective policy areas, the European Commission has issued three Communications to the Council and the European Parliament, starting from the year 2000, which focus on the identification and set up of a framework of agrienvironmental indicators «for monitoring the integration of environmental concerns into the common agricultural policy» (COM(2006)508). According to this latest Communication the framework is now composed by 28 indicators, among which n.28 is defined as «Landscape state and diversity». The Communication also classifies the indicators according to their level of development, which, for the landscape indicator is «in need of substantial improvements in order to become fully operational».

There are clear constraints in the definition of the indicator: it must be calculated on the basis of available data or on information that can be made available in the short term, at the EU level, based on a harmonised methodology. Furthermore the indicator will be applied for monitoring purposes so the need for updates must be taken into consideration.

This paper presents the state of the art of the conceptual and practical implementation of the indicator.

2 Indicator definition

The landscape addressed by the indicator is the one targeted by the CAP, here identified broadly as rural-agrarian landscape. Its mere extension is intended as the soil surfaces where the agricultural activities (cultivations, grazing etc.) take place, plus the areas of natural/semi-natural vegetation functional to the agricultural management (hedges, field margins, ditches etc.), rural buildings and structural elements (dry walls, terraces etc.). As a wider concept the rural-agrarian landscape is a cultural landscape composed by spatial units characterised by the interrelation of different but identifiable components such as natural conditions/farming traditions/farming systems/cultural heritage, and the people who manage the landscape (the farmers).

The rural-agrarian landscape is a subset both of the total landscape and the rural landscape; the latter contains also other types of built-up areas and infrastructures, involving other activities not directly linked to agriculture.

The identified landscape concept can be schematised on the assumption that landscape is structured in different components or layers, and can be described / summarised in four main aspects which represent:

1. the natural potential of the land, which is given by soils, climate, topography, potential vegetation etc.
2. the physical structure, intended as land cover and its spatial organisation as a product of land management (organisation of different land cover types, plot size, fragmentation, diversity etc.)
3. the influence exerted by society on the agrarian landscape with their agricultural activities, and the way such influence is organised (farm practices, farming systems, biomass production etc.)
4. the social perception on the landscape, as the society perceives, reads and assesses landscape quality; the society plans, manages, and uses the landscape for productive or non productive purposes.

These aspects are very different among them; therefore it is unlikely that one indicator can synthesise them all. The implementation of the indicator is therefore carried out through a set of sub-indicators, addressing specifically each of the aspects listed above:

1–3) It can be assumed that the natural potential of the landscape is invariant, therefore rather than proposing a composite sub-indicator referring to these invariant factors an indicator can be selected providing an estimate of how much the actual agricultural ecosystems are distant from a potential natural one (this is a relative assessment therefore variations of the natural potential due to climate change are not relevant in this context). An existing indicator that describes well this aspect is the hemeroby index. The hemeroby provides a measure of the anthropogenic influence on landscapes and habitats (Sukopp, 1976; Wrbka et al., 2004; Fu et al., 2006). The degree of hemeroby increases with the increase of human influence; gradients of human influence are assessed using a scale, in which the lowest values (ahemerob) correspond to «natural» or non disturbed landscapes and habitats such as bogs and the highest values (metahemerob) are given to totally disturbed or «artificial» landscapes and habitats such as artificial surfaces (Steinhardt et al. 1999). When applied to the rural-agrarian landscape the index expresses how much the pressure from agricultural management practices moves the state of the landscape away from the natural one.

2) The physical structure has been widely addressed in literature when analysing landscape composition and spatial pattern (McGarigal et al., 2002). In this specific case two aspects are particularly relevant: the internal structure and configuration of the rural-agrarian landscape, and the structure of such landscape in reference to the overall landscape matrix.

4) The implementation of an indicator targeting the appreciation of the rural-agrarian landscape at European level has been explored as a proxy of the interest/perception that society has for the rural-agrarian landscape. This involves the assumption that such interest can be demonstrated with the regulations on landscape protection and with the use and enjoyment that society makes of this type of landscape.

Point 2 and 4 have been developed and will be presented in the following sections.

2.1 Landscape physical structure indicator

Through the landscape physical structure indicator both the internal structure of rural landscape and the interaction of rural landscape with the contiguous landscape are described. The indices identified to describe these two aspects are the Largest Patch Index (LPI) as a measure of agricultural landscape fragmentation in the matrix of non-agricultural background (McGarigal et al., 2002), and the number of crop categories as a measure of agricultural landscape diversity.

Data from two datasets were taken into consideration: CORINE Land Cover 2000 (CLC2000; JRC-EEA, 2005) and CAPRI (Common Agricultural Policy Regionalised Impact) model database (Britz and Witzke, 2008). CLC2000 provides a good representation of agricultural areas in the matrix of natural vegetation and urban areas. However, CLC2000 classification system does not give any information on the diversity of agricultural crops. The data on crop shares made available in the

CAPRI modelling system, instead, allow an estimate of the share of 30 different crops at 1 km^2 cell resolution for the EU, except for Cyprus and Malta (Kempen et al., 2006).

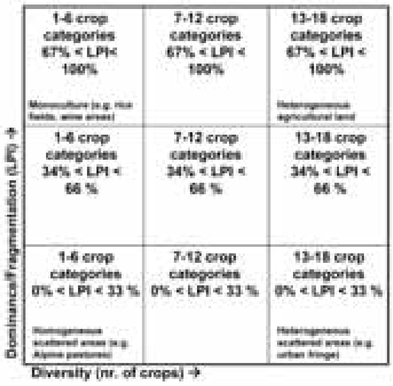
The Largest Patch Index (LPI) was calculated for a 10x10 km cell grid covering the EU27. The CLC2000 raster dataset was split into 10x10 km^2 raster squares, and then reclassified into 2 categories: «Agriculture», including agricultural classes and natural grasslands, and «background», including artificial areas, natural vegetation and water. LPI was then calculated for each 100 km^2 raster square using Fragstat 3.3. LPI ranges from 0 to 100 and is expressed as percentage. Following the above described protocol, LPI measures the extension of the largest agricultural patch in each cell, and thus the dominance and fragmentation of agricultural landscapes.

Likewise LPI, the number of crop categories was calculated for a 10x10 km^2 cell grid covering the EU27. The CAPRI model allocates crops and estimates their share of UAA in homogeneous soil mapping units (HSMU), consistently with statistics at NUTS2 level (Nomenclature d'Unités Territoriales Statistiques, EC 2003). The distribution of 18 crop categories was analysed: cereals, mais, paddy rice, rape, sunflower, legumes, textile fibres, other industrial crops, nurseries, flowers, vegetables, root crops, tobacco, fruits, citrus fruits, olives, grapes, grasslands. The categories have been defined according to their significance from a landscape perspective. The information at HSMU level was aggregated at the 10x10 km grid resolution, assuming that the crops available in each HSMU could be uniformly distributed inside its surface.

Nine landscape structure classes were then created by cross combination of the two indices, as illustrated in Figure 1.

2.2 Landscape appreciation indicator

It is not possible, in the context of a EU wide assessment, to address landscape perception through valuation methods at local level, therefore the interest/perception that society has for the rural-agrarian landscape is modelled with the assumption that such interest can be indirectly demonstrated through the use of proxies, which have been identified on the basis of methodological aspects and data availability at the EU scale: protected agricultural sites, rural tourism, presence of labelled products. The indicator is a linear combination of three indices, which refer to such specific aspects: 1) Quality products, including food and spirits under the Protected denomination of Origin and Protected Geographic Indication schemes, and wines under the Vin de Qualité Produit dans des Régions Déterminées (VQPRD) scheme; 2) Tourism in rural areas; 3) Agricultural areas in protected and valuable sites.



1-6 crop categories 67% < LPI< 100% Monoculture (e.g. rice fields, wine areas)	7-12 crop categories 67% < LPI < 100%	13-18 crop categories 67% < LPI < 100% Heterogeneous agricultural land
1-6 crop categories 34% < LPI < 66 %	7-12 crop categories 34% < LPI < 66 %	13-18 crop categories 34% < LPI < 66 %
1-6 crop categories 0% < LPI < 33 % Homogeneous scattered areas (e.g. Alpine pastures)	7-12 crop categories 0% < LPI < 33 %	13-18 crop categories 0% < LPI < 33 % Heterogeneous scattered areas (e.g. urban fringe)

Figure 1: Scheme of the rural-agrarian landscape structure indicator

The index for quality food and wine was calculated from two different datasets, since the VQPRD wines have not been included in PDO or PGI schemes so far. Firstly, PDO and PGI products linked to landscape state and diversity were selected from the DOOR database (EC, DG Agriculture, http: //ec.europa.eu/agriculture/quality/door/). The selection was based on the following criteria: 1) the product itself creates a specific landscape (i.e. vineyards, olive groves, etc.); 2) the production area is characterized by a particular landscape (i.e. montados, bocages, alpine meadows, maquis, etc.); 3) the production is explicitly related to the preservation of the landscape's characteristics; 4) the production is the result of a traditional management of rural landscape.

A geo-database of the spatial distribution of selected PDO and PGI products was created at NUTS3 level, according to the information on the production areas provided by producers. Then, the number of different labeled product per NUTS2 region was calculated. For VQPRD wines, data on the number of labeled products were only available at Member State level, thus data on the cultivated surface (ha) extracted by the «Inventory of quality wines produced in specified regions» (http: //ec.europa.eu/agriculture/markets/wine/prod/inventaire.pdf) was used, available at NUTS2 level. The index was calculated as the surface under cultivation of quality wines produced in specified regions.

Taking into account that the PDO/PGI index was calculated as number of products whereas the VQPRD index was calculated as hectare of cultivated area, different weights had to be assigned to the two indices in the aggregation procedure. These were calculated at country level, according to the proportion of PDO/PGI products and VQPRD wines on the total amount of labeled products. The number of wines under VQPRD scheme was derived from E-Bacchus database for each country (EC, DG AGRICULTURE http: //ec.europa.eu/agriculture/markets/wine/e-bacchus/). The two rescaled indices were thus weighted and summed.

The second index composing the landscape appreciation indicator is related to tourism activity in rural areas, for which data are both fragmented and incomplete at European scale. Therefore it was calculated according to FSS (Farm Structure Survey) declarations for «Tourism as other gainful activity». The data refer to all activities in tourism, accommodation services, showing the holding to tourists or other groups, sport and recreation activities etc. where either land, buildings or other resources of the holding are used. These data do not represent the whole touristic activity in rural areas, they are, though, the only ones available for almost all Europe, at regional resolution. Data are missing for the following regions: Eastern and South Western Scotland, Highlands and Islands in the United Kingdom and Île de France in France. FSS statistic data from 2001 to 2005 were used, and for each region data were chosen from the last available date. The index was calculated as the number of holdings declaring tourism as «other gainful activity». Per NUTS2 region.

The last index composing the «landscape appreciation» indicator is the share of agricultural area in protected and valuable sites, specifically Natura 2000 sites, World Heritage Unesco sites related to agricultural landscape, European nationally designated areas, and category V – World Protected Areas. Many sites were included in more than one dataset, therefore a unique database was built in order to avoid redundancy. Agricultural areas were extracted by CLC2000 taking into account all agricultural classes and the class «Natural grassland». The index was calculated as the surface of agricultural area included in protected and valuable sites in each NUTS2 region.

The three input components have been standardized to the UAA and rescaled to a 0–10 range by means of Minimum-Maximum (Min-Max) method. Finally, the three indices, equally weighted, were summed up to the final aggrigated indicator which ranges from 0 to 30. The reasons why the regions score high are very different: some have a high rate of protected agricultural area (e.g. Rhein regions and Baden-Wuttemberg), some have a high number of labelled products (e.g. Trentino in Italy for apples and cheese, Norte in Portugal for meat), some have a high number of farms declaring relevant revenue from tourism activities (e.g.Tirol & Salzburg). On the other hand it can also happen that some regions (e.g. Provence-Cote d'Azur) have a high score because they reach medium results in all indicators.

3 Conclusions and way forward

Results obtained so far show that identified sub-indicators can be calculated on the basis of data available at EU level. Obviously a certain degree of approximation has to be taken into consideration, and also the awareness that there are relevant landscape characteristics that cannot be represented in the final indicators, like parcel size or the presence of linear elements, either because the data are not publicly available, as in the case of IACS (Integrated Administrative Control System) data, or because consistent EU surveys are lacking (linear elements). In other cases data exist (tourism in the FSS) but their level of accuracy is not homogeneous across the Member States. In this sense the current exercise has also the function of highlighting the lack of appropriate data to the statistical offices (both at Member State and EU level).

The way forward includes the set up of the methodology and the calculation of the third sub-indicator (based on the hemeroby classification) and a cross validation with studies at the regional scale.

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MONITORING THE COASTAL LANDSCAPES OF ESTONIA

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Abstract

Changes in landscapes are caused both by development of the landscapes themselves and human impact on them. Coastal landscapes are a remarkable part of Estonia. Monitoring of coastal landscapes of Estonia was included in the state environmental monitoring in 1996. The main research methods used are the classical ones: large-scale mapping, comparative cartographic analysis, and the method of landscape profiles. Comparison of data from different years clearly shows much quicker natural processes and better traceable changes on the shores directly influenced by seawater. Traditional activities were interrupted for nearly 50 years during the Soviet occupation when the coast of Estonia was a border zone with military facilities. The development trends over the last century in Estonia show a steady decrease of open landscapes; the landscape pattern and biodiversity of areas have simplified.

1 Introduction

Estonia is a small (45 227 km^2) country by the Baltic Sea. It has long shoreline (3790 km), and thus coastal landscapes comprise a significant part of the country. The majority of contemporary coastal landscapes emerged from the sea during different phases of the Limnea Sea (during 4500 years) in the Subboreal and Subatlantic climatic periods. The landscape structure, development and dynamics of the coastal area under discussion are closely connected with the geological history of the whole Baltic Sea region. The coastal landscapes are very variable and show considerable regional differences. Differentiation of the coastal area has been strongly affected by ancient relief and lithology of the sediments. The development of coastal landscapes is also related to hydrological regime and climate conditions. Coastal landscapes are remarkably diverse with high nature conservation value, which is expressed in the diversity of ecosystems and abundance of habitats. However, coastal landscapes are intensively used with different conflicting interests. Changes in landscapes are caused both by inner development of the landscapes themselves and human impact on them. The main traditional economic activities have been fishing, seal hunting, agriculture, and rarely forestry. The current landscape pattern on the Estonian coast is a combined result of the history of interactions between humans and the environment. Changes in land use have significantly influenced the landscape diversity in Estonia.

2 Materials and methods

Landscape monitoring is regarded as regular, long-term surveillance of a landscape, aiming at early recognition, assessment and prediction of landscape change, and focusing on the effects of human impacts (Syrbe et al. 2007). In 1996 monitoring of the coastal landscapes of Estonia was included in the State Environmental Monitoring Programme. Presently we have 26 coastal landscape monitoring areas (Puurmann et al. 2004). Monitoring data for each area is given according to 17 parameters (incl. archaeological-cultural and nature values, social-economical factors). By the end of 2004, the first round of investigation on all monitoring areas was finished. The work is based on fieldworks and GIS techniques. The main research methods used are traditional:

- Large-scale mapping (1: 10 000). Localities (small landscape typological units) are connected with relief forms and lithological composition of deposits. Landscape fragmentation within localities is expressed by vegetation site types. To characterise landscape diversity the edge index has been used.
- Method of landscape profile. Landscape profiles are compiled to provide a comprehensive view

of the vertical cross-section of the basic landscape units (topography, rocks and sediments, soil, vegetation, land use) and to carry out detailed analysis of mutual relationships and processes between different components. Species lists of vascular plants, bryophytes and lichens are composed.
- Comparative cartographic analysis. On the basis of land cover maps from different periods the landscape changes are analyzed using simple comparison technique. Based on older maps, changes in land cover can be followed back to the beginning of the 20th century.
- Current state of monitoring areas is documented by photos.

3 Results and discussion

Landscape structure of the coastal region is rather diverse. In studied areas usually 7–9 types of localities and 12–14 vegetation site types can be distinguished. Their edge index is very variable. The coastal areas can be divided into a narrow shore and inland areas. The shores are directly affected by seawater, wave action and sea ice. In recent decades, severe coastal damage in Estonia has been often caused by a combination of a strong storm, high sea level and absence of ice cover (Orviku et al. 2003). In last years the most extensive changes caused by shore processes were observed in the Harilaid monitoring area, when the 2005 January storm caused clearly visible changes. In silty and till shores, where the coastal sea is shallow and storm waves vanish or weaken before reaching the shore sodding takes place. On these shores seashore meadows with halophilous vegetation on Salic Fluvisols are developed. Periodic inundation by seawater plays decisive role in the formation of seashore vegetation, determining the specific moisture regime, as well as the content and distribution of chemical elements in the soil (Ratas et al. 2006). Seashore meadows are more widely distributed in West Estonia. As a result of land uplift (presently up to 2.8 mm/year) the soil-vegetation complexes of seashore meadows have undergone a series of development stages from hydrolittoral to epilittoral and one plant community has been replaced by another. The quicker changes in the vegetation of seashore meadows have occurred after cessation of grazing and haymaking. Also, strong storms have carried a thick layer of drift litter (seaweed) into the lower part of the shore, where the material rich in nutrient elements has caused drastic changes in topsoils, making the plant cover mosaic and dominated by nitrophilous species.

As a rule, the more inland from the shore, the older the landscapes and the more stable the natural processes. In most cases human activities affect directly the plant cover and landscape pattern. The main traditional economic activities in coastal areas have been fishing, seal hunting, agriculture, and forestry. Depending on variations in edaphic conditions, generally two landscape types can be distinguished in coastal areas: agricultural landscape and woodlands. Cultivation of coastal areas started on higher elevations. Due to lack of new land naturally suitable for cultivation the majority of fields have remained in the same place for centuries. Hayfields were located on lower ground on Gleysols. The coastal areas of some regions were most heavily forested due to sandy soils unsuitable for cropland. The conditions for clear cutting were also unfavorable, due to the value of forests in protecting soil, and usually these areas have been forested for centuries. Specific problems have resulted also from the long history of forest protection. For example, in 1764 a law was passed that declared woods within 50 fathoms of the island and mainland coasts to be protected zones in order to preserve their silhouettes for seafarers to orient themselves.

The socio-economic situation on the territory of present-day Estonia has changed at least five times during the past century (Mander & Palang 1999). The systems of land division have played an essential role in the formation of landscape pattern. The most intensive exploitation of the coast occurred from the middle of the 19th century to 1940. World War II and the socialist order altered the way of life during the next 50 years, when the coastal area became marginal land of collective or state farms. Another important factor in the changes was the leaving of or significant reduction in the local population. Most of the Estonia's coast was proclaimed a border zone of the Soviet Union, which led to perishing of the traditional lifestyle in the most part of coastal areas where man had been utilizing and shaping the landscape for centuries. Coastal settlement together with traditional rural landscapes like wooded meadows and coastal pastures started to disappear. In places where the original population remained, the changes have been similar, but slower and less extensive. The latest change, the reprivatisation of land, was launched in early 1990s, but the coastal landscapes will not be managed in the traditional way. Nowadays a great part of coastal areas is protected and belongs to the

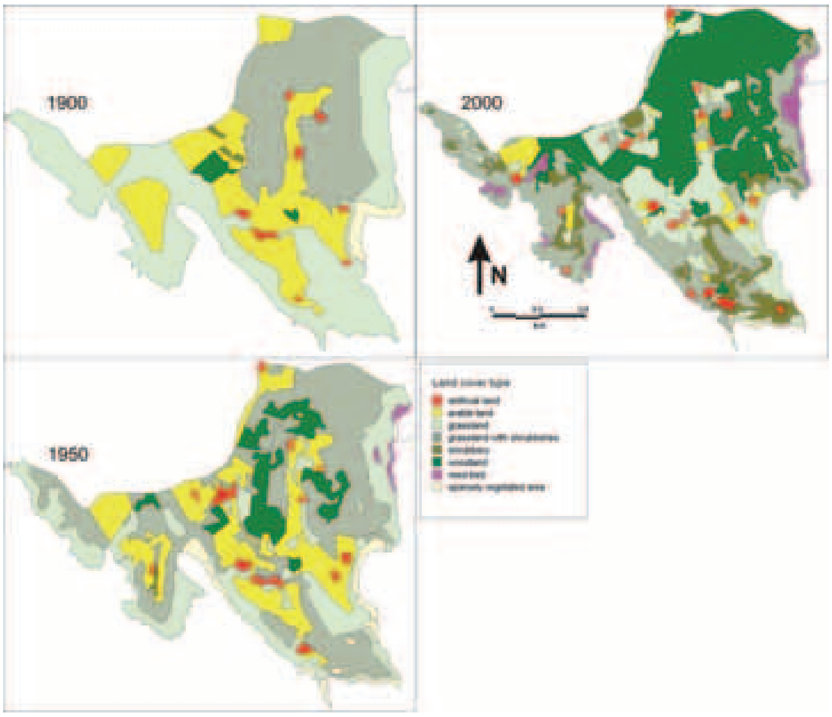

Figure 1: Land cover maps of Tõstamaa monitoring area from 20th century.

ecological network of the European Union – NATURA 2000.

The current socio-economic changes and cessation of traditional activities have led to ecological and visual degradation of agricultural land. Analysis of the monitoring areas' land cover shows the following changes in coastal landscapes: decrease in arable land, replacement of grassland by shrubberies and reed beds (Figure 1).

The above mentioned trends have caused simplification and impoverishment of the landscape pattern. Changes in the vegetation of grassland occur after cessation of grazing and haymaking – more diversified plant communities are replaced by reed beds. After the grazing has ceased, the share of trees and shrubs has increased and the wooded meadows alternate with forest and the light conditions and therefore species composition in vegetation herb and ground layer have greatly altered (Figure 2).

Plant cover type: **tr**, paludified forests *Carex* site type; **Kd**, juniper shrubbery; **Lok**, dry alvar meadows; **Aan**, moist boreal meadows; **Sor**, species-rich paludified meadows; **Ras**, suprasaline seashore meadows; **Rap**, coastal reed-bed; **Rt**, coastal initial vegetation.

At the same time, changes in coastal forests are usually rather small, indicating mainly different stages in their development: clearing → young stand → mature forest (Ratas et al. 2008). Changes within forest landscapes are mainly caused by alternation of forest generations, accompanied by the change of the species composition of trees. For centuries the character of coastal forests has been affected also by heavy storms as well as forest fires. Nowadays the forest fires in Estonia are closely linked to human activities. The most extensive forest fire took place in 1951 in Keibu monitoring area. Afforestation is one of the most serious threats for open coastal landscape. Nowadays coastal aeolian landscapes possess mainly recreational value and their intensive exploitation may have unfavourable consequences. Recreational activities on sandy shores occur mostly in summer (from June to August). The more intensively used forestry areas

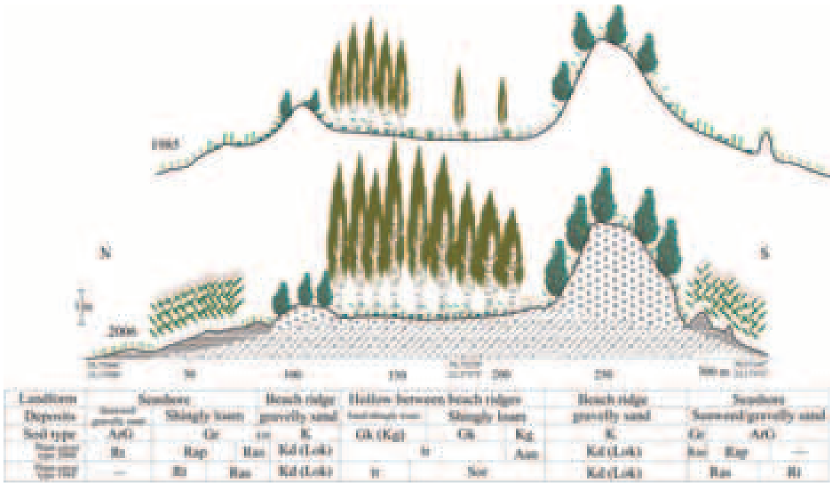

Figure 2: Landscape profile of Islet Kõverlaid in 1985 and 2006.

Abbreviations

Soil: **K**, Cambi-Rendzic Leptosols; **Kg**, Cambi-Gleyic Leptosols; **Gk**, Cambi Rendzic Gleysols; **Go**, Cambi Calcic Gleysols; **Gr**, rarely flooded Salic Fluvisols; **ArG**, frequently flooded Salic Fluvisols;

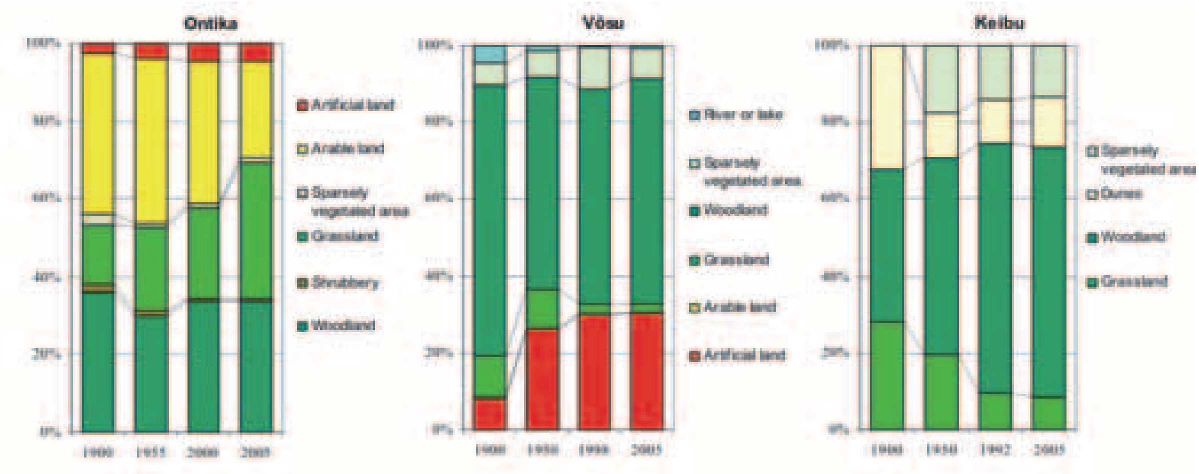

Figure 3: Land cover changes in agricultural landscape (Ontika) and woodland (Võsu, Keibu).

are located in the immediate proximity of the popular sandy beaches. Coastal dunes and ancient sandy beach ridges are very fragile ecosystems that can be easily destroyed by trampling. During the last decades private residences and summerhouses have replaced coastal forests in the vicinity of towns.

The development trends over the last decades show a steady decrease of open landscapes, first of all grasslands, and increase of shrubberies and forests (Figure 3). These changes have caused habitat loss and alteration, and landscape changes influence a wide range of countryside interests. The data on monitoring areas reflect diversity of coastal landscapes and problems connected with their conservation. The task of nature conservation is to protect and preserve the landscape, including rare animal and plant species and their biotopes. Nature conservation forms a part of the culture of a country. The data of coastal landscape monitoring can be used also in general and detailed planning of coastal areas, in making conservation and management plans, as well as in applied research and educaton.

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MAPPING OF VEGETATION IN NORWAY

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Abstract

For almost 40 years the Norwegian Forest and Landscape Institute (Norsk institutt for skog og landskap) has mapped vegetation in Norway. In total, just over 10 % of the country's land area has been mapped, most of which is in the mountain regions. The resultant vegetation maps are the closest Norway has to an ecological map series. Many secondary map themes can be derived from the vegetation map and the digital format allows a wealth of both spatial and temporal GIS-analyses. Accordingly, there are many user groups and topics of interest. During 2009 the aim is to make the institute's vegetation maps available to all via the Internet in a seamless database.

1 Introduction

Vegetation mapping is defined in a wealth of ways, but historically the classification of vegetation types was closely related to the discipline of phytosociology (Braun-Blanquet 1965, Küchler & Zonneveld 1988). Today, however, the term vegetation mapping is used for a broad variety of spatio-temporal classification and mapping systems for the analysis of different aspects of vegetation at almost any scale (Alexander & Millington 2000). There seems to be no worldwide consensus on the definition of vegetation mapping, and the methods for mapping are as varied as the classification systems.

The presented vegetation mapping system is derived from the Nordic school of phytosociology, but simplified to a smaller map scale with fewer classes and adapted to fieldwork involving aerial photo interpretation (Rekdal & Larsson 2005). This method of vegetation mapping captures the extent of structural vegetation types at a specified scale or landscape level (Wyatt 2000, Ihse 2007). A vegetation map thus represents a spatially simplified map showing vegetation classified according to predefined types.

The vegetation types represent more or less stable entities of plant communities characterized by physiognomy, plant species composition and/or indicator species, or a combination of all three, and they are influenced by a number of ecological processes through time and space (Fremstad 1997, Alexander & Millington 2000, Bryn 2008). Non-vegetated areas are mapped according to a variety of characteristics.

2 History

The first vegetation map in Norway based on defined plant communities became available in 1937 (Mork & Heiberg 1937). In the following years and up until the end of the 1960s, little mapping was done, but a number of central studies were carried out on plant communities which formed the basis for later mapping systems.

In c.1970 work was first started on more comprehensive mapping of vegetation in Norway. Several research communities worked on the development of systems for practical mapping. This led to Norway having a number of mapping systems, which undoubtedly had strong common traits but were also strongly characterised by the parts of the country from which the data had been collected. Much work was carried out through the International Biological Program (IBP), which also involved extensive Nordic collaboration.

A considerable amount of vegetation mapping was done throughout the 1970s and at the beginning of the 1980s, mostly in connection with the development of water resources. From 1973 the institute developed a more general mapping system whereby more information could be collected from aerial photos. In 1979 the institute was commissioned to map a number of watersheds where hydropower development was planned. This provided impetus for the development of mapping systems and methods adapted for presentation at 1: 50,000 scale. Most of the vegetation mapping in Norway in the last 20 years has been undertaken by the Institute in accordance with this system.

In 1982, initiative was taken to establish a nationwide system for detailed mapping (1: 5000–20,000). A group was appointed and subsequently presented its final draft in 1987 (Fremstad & Elven 1987). The group's work revealed a great need for extensive research within a number of vegetation groups in Norway. It was intended that their work should be followed up and revised whenever new knowledge became available. Yet despite this, the work on plant communities for vegetation mapping was given much lower priority by researchers in the 1980s and 1990s, to the extent that there were almost no developments in this field. Nevertheless, a revised version of plant communities for detailed mapping was published in 1997 (Fremstad 1997).

3 Mapping system

Today there are two mapping systems in Norway which give more or less complete national coverage: one for detailed mapping at 1: 5000–20,000 (Fremstad 1997), and one for more general mapping at 1: 25,000–50,000 (Rekdal & Larsson 2005). The data on vegetation types from the detailed system can be combined with data relating to vegetation types in the general system.

The detailed system has three levels, namely groups, types and subtypes. There are 24 groups which together account for the main types of vegetation. The system contains 137 types, which normally correspond to plant communities on different levels. In turn, the majority of types are further divided into subtypes which correspond to plant communities on lower levels (association, sub-association). Regional variants or special local communities are usually counted as types. The system contains many communities on spatial levels that are not possible to map and are therefore better suited for detailed vegetation descriptions or mapping for research purposes.

The mapping system designed for general surveying is far cheaper since labour costs with fieldwork is high. Identification of types is developed more on the appearance of vegetation (i.e. physiognomy) to the extent that it is characterised by dominant species or species groups. The system divides the vegetation types into 10 groups, which in total comprise 45 vegetation types and 9 other land cover types.

In both systems a number of additional symbols are used for important information which is not included in the type definition; examples include coverage of lichen, willow thickets, willow, juniper, matgrass, and grass-rich forms. In addition, the systems have close similarities with the system used for mapping mountains in Sweden and Iceland.

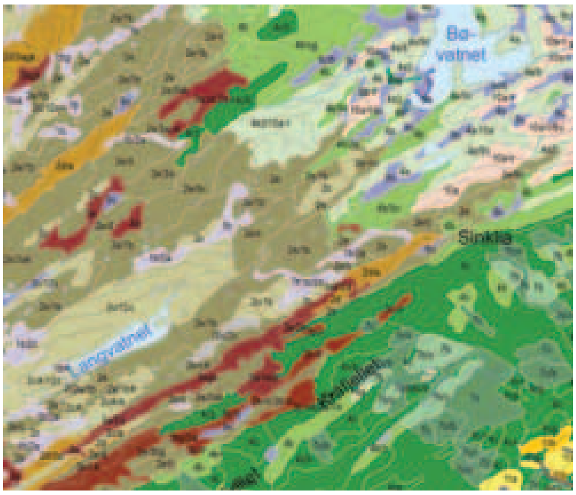

Figure 1: Vegetation map from Ballangen Municipality, North Norway (Bryn 2005).

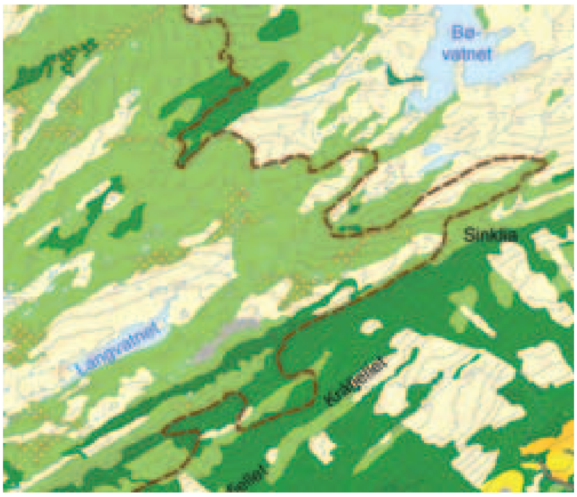

Figure 2: Map of sheep grazing qualities derived from the vegetation map in Figure 1 (Bryn 2005).

4 Data collection

The method of data collection for vegetation mapping in Norway is primarily based on fieldwork and the use of aerial photos. Detailed mapping requires labour-intensive fieldwork and the recording rate is 0.5–1 km^2 per day, depending to some extent on the complexity of the vegetation. In contrast, survey mapping is based far more on the interpretation of aerial photos, and in this respect visual contact is similarly made with most of the land under survey. The survey mapping rate is 3–5 km^2 per day.

To date, we have mostly had access to black-and-white aerial photos as mapping resources. Now digital photographing in colour is underway for the whole country at a scale of 1: 35,000, and this will be repeated at 5–7 year intervals. We have also carried out some mapping using colour infrared photography (CIR). Our experience shows that this gives more reliable mapping (Ihse 2007), but it does not increase the spatial progress of fieldwork to any significant extent.

During mapping, plot-analysis of species composition is carried out in order to document the development of vegetation types in given project areas. Normally, approximately five $10m^2$ sample squares are analysed for each vegetation type. The Institute now has a database of plot-analyses from locations throughout the country. The analyses yield information on the coverage of, for example, different plants, the sample squares' angle of slope, and height above sea level.

There have been high expectations regarding the use of satellite images for vegetation mapping since the early 1970s. In Norway, several research communities have attempted routine mapping without having had any great impact, but a new nationwide vegetation map based on satellite photos is being prepared by NORUT (Northern Research Institute). At the Norwegian Forest and Landscape Institute the mapping of land areas above the forest limit has been carried out for five area classes based on the interpretation of satellite images. The results are presented in the map series AR250, which will be completed in 2010. The Institute has made several attempts at using satellite images for mapping vegetation in the mountains of Norway. The results show that mapping of traditional vegetation types cannot be carried out using either supervised or non-supervised methods.

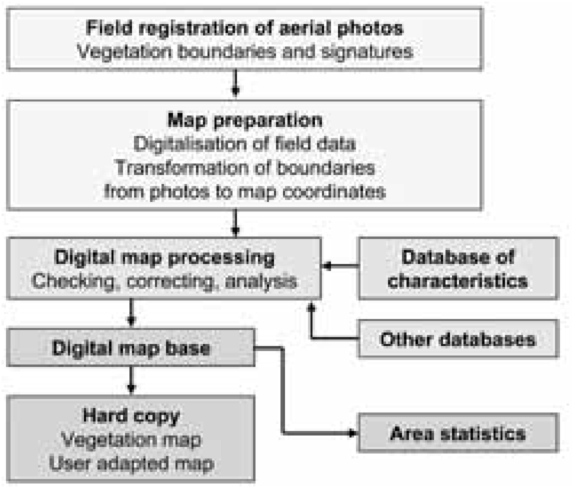

Figure 3: Production of vegetation data by the Norwegian Forest and Landscape Institute.

5 Map production

The vegetation maps are produced using digital mapping techniques. Vegetation boundaries and signatures are now mostly digitized from orthophotos. A data program is used to correct for errors which occur in the aerial photos as a result of the different angles and altitudes at which the photos were taken. Rectified digital data are synthesized using a geographic information system (GIS) with modules for storage, processing and presentation of data. The resulting map database forms the starting point for the production of thematic maps, analyses and plots. The Institute's map database is then combined with data from other map databases, such as contour lines, water bodies and roads from Statens Kartverk (Norwegian Mapping Authority).

The handling of vegetation data in a GIS system gives possibilities for analysing and presenting the diverse information contained within a vegetation map. By exploiting ecological knowledge of the vegetation types, we can derive databases of the vegetation types' characteristics for many basic topics. Combined with other digital map data this gives possibilities for generating a number of other products and analyses, using both thematic maps and area statistics. The presentation of the information in the vegetation map can be adapted to the theme in focus. Combining such databases, including other thematic maps, and performing spatio-temporal modelling or other GIS-analyses, all increase the potential use of vegetation data still further.

6 Funding

The vegetation mapping undertaken by the Norwegian Forest and Landscape Institute is part of a national programme for mapping resources in outfields (*utmark*), and priority is given to the mapping of land for agricultural purposes. User interests account for up to 50 % of the costs, and hence can determine where mapping is carried out. This in turn ensures the continuation of the mapping and at the same time ensures that important outfield areas are prioritised. User funding most often takes the form of joint funding provided by the different parties with vested interests in a given area.

7 Vegetation mapping in the future

As a map series, vegetation maps provide the most comprehensive knowledge about the natural resources base in a given area. Potentially, such maps should have many contemporary users groups', but in Norway there have not been any strong user groups proclaiming the need for vegetation maps. The new possibilities which have arisen with GIS-technology have made it far easier to market the maps, and the production rate is increasing. It is now possible for the Institute to present information adapted to users' needs.

Much indicates that the demand for data based on natural resources will increase. In Norway there is increasing conflict between interested parties over outfield areas. This concerns, for example, economic exploitation, development, outdoor activities, and nature protection. In the future, a number of interest groups are likely to want to be involved in deciding how outfield areas should be managed. It will therefore be important for both traditional and newer users to make their interests known and plan their land use. Thus, multiple use will become an important keyword in all land use.

With the present prospects for funding, vegetation mapping in Norway is likely to be carried out on several spatial levels in the future. Field-based mapping will mainly be used where there is a need for in-depth knowledge of natural resources, such as national parks and other protected areas, land affected by planned encroachments into natural areas, important economic areas, areas of conflict, as well as for scientific purposes (Bryn 2009). However, most of the mapping will probably take the form of surveys, where data relating to the resources of large areas will have to be mapped using satellite-based techniques.

For a number of years, The Norwegian Forest and Landscape Institute has been working on making vegetation maps a good tool for planning grazing, and to serve as an aid in the management of domestic grazing areas and their biological diversity. In recent years, the economy linked to grazing has become the most important source of commissions for vegetation mapping.

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INTEGRATED ECOFOREST MAPPING OF THE NORTHERN PORTION OF THE BOREAL ZONE, QUÉBEC, CANADA

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Abstract

The boreal zone covers 71 % of Québec's land mass, or over 1,000,000 km². This zone is constituted of balsam fir, spruce-moss, spruce-lichen open forest, and tundra forest. The vegetation of this huge area is well documented for some portions and poorly documented for others. Since the late 1960s, Québec's Ministère des Ressources naturelles et de la Faune (MRNF) has periodically carried out forest mapping activities at a scale of 1: 20,000 in the southern portion of boreal zone. For the area marking the northern portion of the spruce-moss forest and the southern extent of the spruce-lichen forest, characterized by sparser forests and barrens, the MRNF has developed an automated mapping approach at a scale of 1: 100,000.The present paper proposes an adaptation of the methodology used at the scale of 1: 100,000 to a smaller scale (for example,1: 1,000,000) for the northern portion of the boreal zone.

1 Introduction

Since the late 1960s, Québec's Ministère des Ressources naturelles et de la Faune du Québec (MRNF) has periodically carried out forest mapping activities at a scale of 1: 20,000 (Robert & Robitaille 2009a, 2009b) in southern Québec (Figure 1, sector 1).

In the early 2000s, the MRNF developed an automated mapping approach at a scale of 1: 100,000 for the area marking the northern portion of the spruce-moss forest and the southern extent of the spruce-lichen forest, characterized by less dense forests and barrens (Figure 1, sector 2). The mapping of this territory of 240,000 km² is partly completed. This approach was presented at the workshop Circum Boreal Vegetation Mapping in 2008 in Helsinki (Robitaille & et al. 2008).

This paper presents an adaptation of the methodology developed by the MRNF at a scale of 1: 100,000 to a smaller scale (for example, 1: 1,000,000). This methodology could be applied to the 516,000 km^2 of land in the spruce-lichen open forest domain and the tundra forest domain (Figure 1, sector 3). In order to test the approach, two study sites located in the north and centre of the province of Québec were chosen, covering several representative vegetations types. Physical variables were acquired from topographic, geologic and surficial deposit maps. The vegetation variables were acquired from remote sensing data. Last, the integration of major disturbances with all the above variables completed the small-scale integrated ecoforest map. This integration approach is similar to the one proposed by Sayre & et al. (2009).

2 Mapped area

The territory is characterized by multiple reliefs, different types of bedrock, altitude and climate zones, major fires and insect disturbances, continuous, discontinuous or sporadic permafrost zones and by various types of surficial deposits which influence the nature, composition and spreading of vegetation.

For instance, along a west-east axis at the 53rd parallel North (the frontier between sectors 2 and 3; Figure 1) the altitude progresses from sea level to about 500 m. The terrain is gentle. In the west-central portion, the relief is gentle but the altitude increases from an average of 500 m to 700 m. There are also a few high hills with rugged topography up to 1000 m in altitude. The east-central portion is very rugged, with height differences that are frequently as great as 500 m. Several peaks reach 900 m. Climatic variables on this axis are described by Proulx et al. (1987):

- Average annual temperatures range from 0 to 1°C on the west coast but are about -4°C in the centre of the territory.

- Average annual precipitation is greater in the centre, with 1000 mm and more on the higher peaks. It is less than 800 mm toward the west.
- Growing degree-days drop from 1100 degree-days in the west to nearly 500 in the centre.

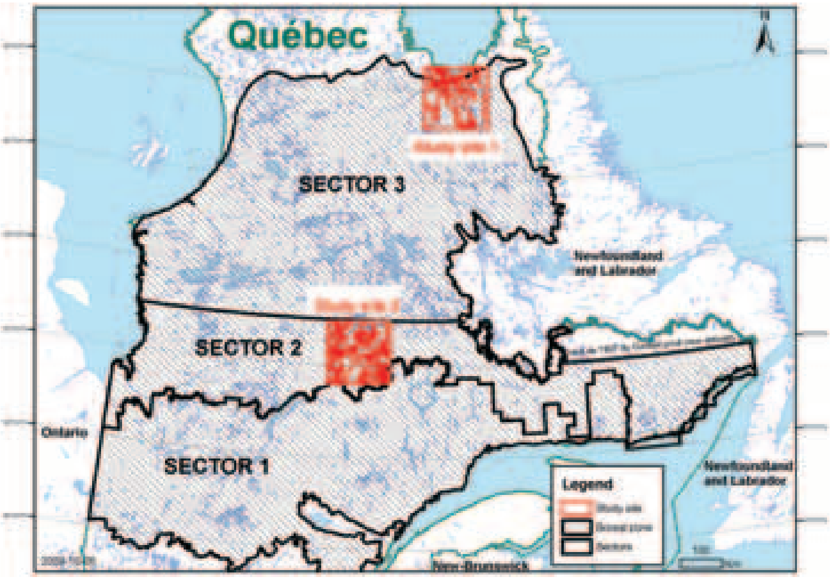

Figure 1: Description of boreal zone, the mapping sectors and the two study sites.

3 Classification structure

As previously mentioned, the classification structure of the mapping is similar to the one developed farther south (Figure 1, sector 2) and integrates environment and vegetation variables (Létourneau et al. 2008, Robitaille et al. 2008). Here are the major classes of this structure.

Surficial deposit and bedrock geology

The composition of surficial deposits influences soil development, vegetation productivity and drainage conditions and is a significant variable in land-use planning. The classes selected for the mapping refer to the major genetic groups (glacial, fluvial, marine, etc.) which have been used for low scale mapping all over Canada (Fulton 1995). Most of these classes are split into subcategories that are distinguished by compactness, granulometry and stoniness. In the absence of surficial deposits, the nature of the rock substrate (ex. igneous, calcareous, etc.), which influences vegetation composition, will be detailed. This information will be acquired from previous work by the MRN (1993).

Vegetation

The classes of vegetation are adapted to the MRNF's needs at this stage in the project, and the tools used allow them to be well recognized. Seven major characteristics can be used to describe the stands.

1. Cover type (deciduous, mixed or coniferous).
2. Understory vegetation (lichen, moss, shrubs).
3. Density classes (five classes from 10 % to 100 %).
4. Disturbances (fire, insects).
5. Development phase (mature, pre-mature or regeneration).
6. Vegetation without forest potential (wetland, barren, etc.).
7. No vegetation (water, rock, etc.).

The maps produced by this approach, along with possible field work and bioclimatic data, will be used to determine the limits of the sub-ecological domains and ecological regions within the MRN framework (MRN 2003). Other variables related to northern environments (ex. permafrost) will also be added to the maps.

4 Approach and tools

The mapping approach includes three principal elements (Figure 2): (1) first, bedrock geology (2) second, surficial deposit boundaries and (3) third, vegetation. This information provides from topographic and geological maps (MRNF 1993) and from surficial deposit maps (Fulton 1995). The polygons generated by these maps are then integrated with Definiens software (Definiens Inc. 2006). For each polygon, the software performs segmentation and classification of the vegetation, based on satellite imagery, Modis in this case. Image segmentation consists of automatically delineating polygons based on thematic maps and image homogeneity patterns. The user controls the size of polygons and smoothness of contours. Cover type, density, barrens, spruce-lichen and spruce-moss forests are then distinguished by analysts, using spectral characteristics of images and ancillary data such as topographic maps, fire and insect history maps, etc. Finally, contours and years of

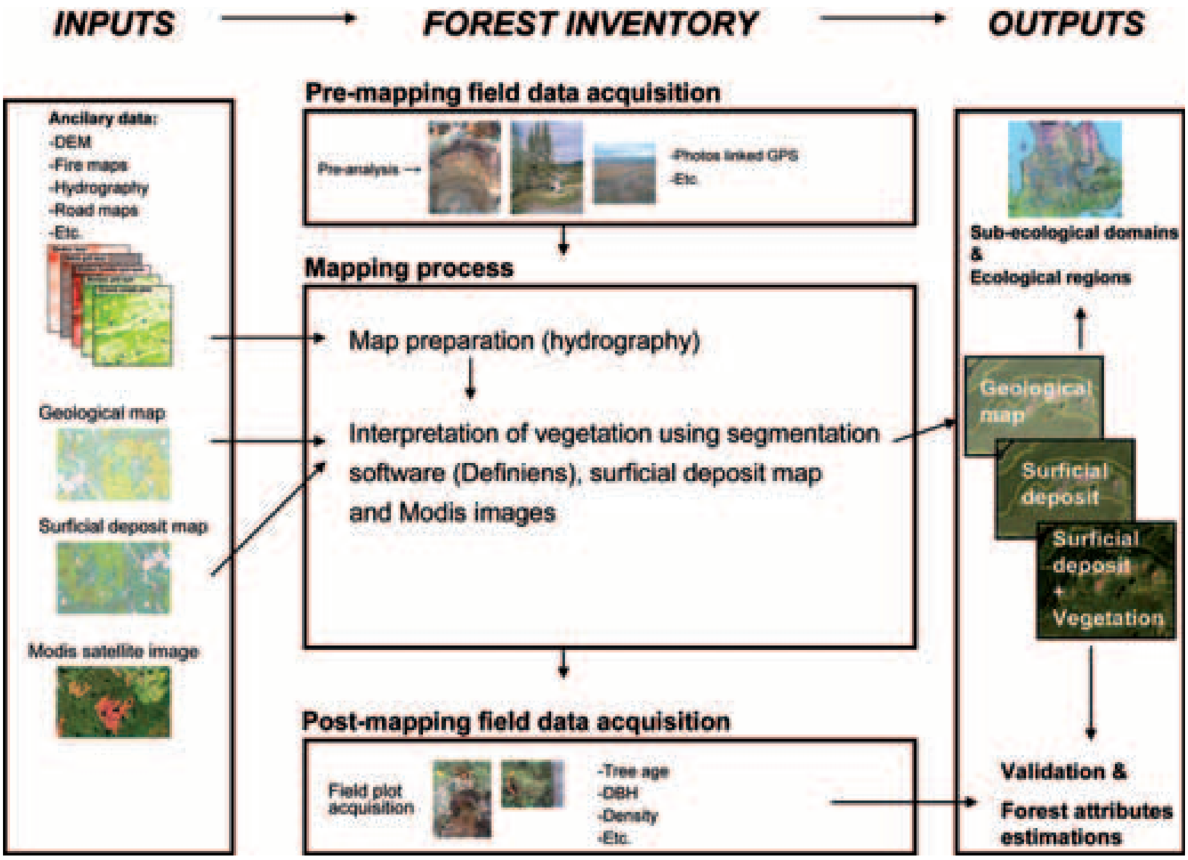

Figure 2: Northern forest inventory process.

major disturbances, such as forest fires and insect epidemics, are integrated into the map. Integrated ecoforest mapping includes prior field checks by geomorphology and forestry specialists to guide and validate the process.

5 Results and discussion

The two study sites mapped have demonstrated that the approach could be applied throughout sector 3. The small scale map approach developed by the MRNF for the northern part of the boreal zone would provides an excellent picture of the vegetation and the physical environment of these vast, poorly-known areas. In fact, a substantial amount of information about surficial deposits, bedrock geology, vegetation and disturbances will be essential to improve our knowledge about this fragile ecosystem. This type of map could be the first step in a regional framework of ecological classification. For each polygon there would be information about the potential natural vegetation and other regional parameters (for example, permafrost).

Last, in spite of the limitations observed, the approach achieves good precision rates and requires little investment, since satellite images cover large areas and archived data can be used to map surficial deposits and bedrock geology. These conclusions pave the way to extrapolating this approach to other remote areas in the boreal zone.

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LARGE-SCALE VEGETATION MAPPING IN ESTONIA

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Abstract

Vegetation mapping of the plant cover of Estonia started in 1930s and was completed in 1965 when detailed overview written by prof. L.Laasimer has been published. Based on field work of numerous botanists the map in scale 1: 42 000 has been drawn. At the end of 1950s the detailed methodology for large-scale vegetation mapping and system of site types has been elaborated. The main activity was addressed to inventory of flora and vegetation of protected areas. During 30 years numerous vegetation maps mainly in scale 1: 10 000 have been compiled. The value of vegetation maps is increasing in time because they reflect not only the situation at the moment of mapping but are excellent basis for monitoring the dynamics of plant cover. Repeated vegetation mapping allows to investigate changes in plant cover, explain their reasons and helps to apply proper means in nature conservation.

1 Introduction

Vegetation mapping is a very special branch of science because it is a synthesis of two earth sciences – geography and plant ecology.

Vegetation mapping has several different purposes:

1. inventory of plant communities, perfoming their spatial location and geographical distribution;
2. vegetation map is a scientific tool for discovering relations between vegetation and abiotical factors (soil, microclimate etc.);
3. vegetation maps enable to measure the tendencies, directions and speed of changes in the whole landscapes;
4. vegetation maps form the scientific basis in land use planning.

The history of vegetation mapping in Estonia can be divided into 3 separate periods (Masing 1991):

1. compiling the vegetation map of Estonia (1934–1958);
2. mapping of the selected territories (since 1958, especially protected areas);
3. repeated vegetation mapping on selected territories.

The first period started in 1934 when professor T.Lippmaa from the University of Tartu following an appeal of the 5th International Botanical Congress organized the team of local botanists (professionals, but also teachers, physicians, chemists etc. took part in vegetation mapping). The mapping was planned for 7 years and the process was very successful (in 1940 already 60 % of Estonian territory has been mapped). One special addition in Lippmaa`s plan was the intention to compile also the map of potential vegetation. Maps of such kind reflect the natural and anthropological changes in vegetation and demonstrate the maximum potential distribution of contemporary vegetation on certain territory. Unfortunately the Second World War interrupted mapping activity, many botanists left Estonia and T.Lippmaa himself was killed during one bombing attack of Tartu. The vegetation mapping continued after the war in 1946 and was led primarly by professor L.Laasimer. By 1955 the field work has was completed and several papers written by L.Lasimer (1958; 1965) were published.

The second period of the vegetation mapping is related with re-establishing nature protection system in Estonia. In 1957 the first nature protection law in the Soviet Estonia has been accepted and as a result a network of nature reserves was established. At the same time the need for inventoring of fauna, flora, vegetation and landscapes of these protected areas arose. This period lasted approximately 30 years and the activities were carried out mainly by the Department of Botany and Ecology of Tartu University (vegetation mapping was one part of 2nd year students field course) and the Estonian Forest Research Institute (the section of nature protection).

After achieving independence the whole system of scientific institutions and universities in Estonia was reorganised. Both because of change economical situation as well as the new directions in scientific field the vegetation mapping as an outdated activity has essentially decreased. However, since 1990s new perspectives for vegetation mapping have been opened. Due to the possibilities to use aerial photos of excellent quality, development of geoinformatics and statistical data processing there is a good chance to analyse vegetation maps and plant communities from different aspects of ecology.

2 Material and methods

In the first period the vegetation mapping of Estonian territory was carried out in scale 1: 42 000 and the Russian topographical map was assigned for the basis. The whole territory of republic has been divided into 350 map sheets and the area of every sheet was approximately 135 km². Afterwards there was a plan to generalize this map to scale 1: 200 000. For botanists taking part in vegetation mapping T.Lippmaa compiled a detailed instruction. The system of vegetation classification units consisted 42 different community types and for every type special shape of signs has been represented. Before the field work on the basis of topographical map the most reasonable plan of routes has been elaborated. The main task was to analyse every vegetation unit that could be found on the territory under study. In every distinguishable vegetation unit the vegetation cover has been described: tree and shrub layer on the plots of 10 x 10 m, field layer on the plots of 2 x 2 m and ground layer on the plots of 1 x 1 m. For every species the abundance estimation in Braun-Blanquet scale (1–5) has been given. For tree layer the mean height, age and density has been estimated. In addition the soil profile has been described, pH of each stratum was measured, water regime and microrelief have been described. After the war the vegetation mapping continued to apply principally the same methodology.

In the second period the methodology of mapping and designing of maps has been improved, especially by professor V.Masing and J.Eilart (Eilart, Masing 1961). The vegetation mapping in this period was carried out mainly in scale 1: 10 000 and 1: 25 000 (sometimes even in scale 1: 5 000). Comparing to the first period the field work methods remained mainly the same but now special printed forms had to be fulfilled and all kinds of human and animal activities were to be documented and their intensity estimated. One of the main advantages was the application of the unified vegetation unit system based on vegetation site types. Another important addition was a logical legend for designing coloured maps. Some most essential principles are the next: 1) dry forests and grasslands are represented by «warm» colours (red, yellow), mesotrophic site types by green and moist site types by «cold» colour (blue); 2) the origin of grasslands has been taken into account (the same colour as correspondent forest, but less intensive); 3) dominating tree and shrub species have been given on maps by special signs; 4) also, the human activity has been represented on maps too (drainage, grazing, clear-cut activity etc.). The maps were drawn by hand.

In the third period the vegetation mapping in field is also carried out by the previous methodology but now more modern technical support is available. The aerial photographs are of good help for orientating in nature, the preliminary boundaries of vegetation units, location of sample plots, rare and protected species can be fixed be GPS-devices. The main new challenges are connected with ecological analysis of vegetation maps, the repeated mapping and discovering the changes in plant cover and the reasons. The vegetation maps are designed and drawn by computer programs (ArcView, MapInfo), the data collected on sample plots are classified and ordinated by modern statistical programs too. In ecological analysis of vegetation maps the next aspects have been highlighted: 1) the distribution of species richness, 2) distribution of evenness, 3) distribution of plant communities due to different ecological demands (calculated on the basis of Ellenberg`s indicator values). The comparison of vegetation maps of different time periods can be proceeded by analysing the change of plant communities and more precisely, by changes in areas of plant communities.

3 Results and discussion

The main result of the first period was the completed large-scale vegetation map of Estonia in scale 1: 42 000. The originals of these hand-drawn map sheets are deposited in Estonian University of Life Sciences and can be served as basis for comparison with maps compiled in next time periods. This large-scale original vegetation map has never published because it was a secret material during Soviet time. It was generalized in scale 1: 600 000 and published as a small-scale schematic map in encyclopaedias, school atlases and as a part of large-scale vegetation map of Soviet Union. The other important result of the mapping process was the elaboration of the methodology for large-scale vegetation mapping, vegetation unit system and principles of compiling the maps. Huge geobotanical material (descriptions of vegetation communities) gave an adequate picture about the botanical diversity of Estonia that became the basis for phytogeographical and geobotanical division of territory of republic.

Some plant ecologists (Box & Fujiwara 2005) have emphasized that nowadays in world scale in many exceedingly urbanised countries with highly disturbed nature the mapping of natural (potential) vegetation has become extremely actual. In Estonia the first map sheets of potential vegetation have been compiled already in 1930s and the survey of main vegetation site types dominating on this map is represented by L.Laasimer (1965).

In the second period approximately 25 protected and potentially protected areas have been mapped in scale 1: 5 000 to 1: 25 000. These maps are valuable sources for understanding the distribution of rare plant communities and species in Estonian territory and so these became the basis for planning nature conservation and tourism. During the destination of Natura2000 areas these materials were also very valuable. In early 1990s A.Kalda (1991) made one far-reaching statement that large-scale mapped territories can serve as key-areas in future when using aerophotographs, as the comparison of mapped and unknown territories will help to compile maps without extensive field work.

In the third period the large-scale vegetation mapping has been continued and nowadays the cooperation between plant ecologists and zoologists must be mentioned. For instance, some vegetation maps of important bird areas have been compiled and relations between different bird groups and vegetation site types have been distinguished (cf. Leito et al. 2006). Ecological analysis of plant communities has been carried out from the point of view their species richness, evenness and demands against several environmental factors on some small protected islands (Mägi 1995; 1997).Another direction is related with repeated mapping and comparison of vegetation maps of different time periods. Both natural and anthropological changes have been discovered. For example, comparison of maps of Harilaid Peninsula demonstrated the next major changes: 1) the area of forests has incresed 16 times (as a result of sowing pine seeds in1930s and planting in 1970s), but natural spread of tree species has also taken place; 2) instead 1 forest site type in 1935 (*Vaccinium vitis-idaea*) in 2001 4 site types were present (*Cladina, Vaccinium vitis-idaea, Oxalis* and *Carex* site types); 3) the area of dry grasslands has decreased and these areas are covered by forest; 4) the most significant changes have taken place on coastal areas as a result of very active coastal processes (as a result of erosion of coastal dunes some species and of plant communities are disappearing and as a result of accumulation processes some are spreading on larger territory than before (Altnurme 2007).

It must be empasized that from the very beginning of vegetation mapping the great attention to abiotic factors (especially soil and water regime) has been paid. So we may draw conclusion that all vegetation maps have been ecological ones. In modern plant ecology the vegetation mapping is usually proceeded by interpreting satellite images and it gives sufficient results in case of small- and middle-scale mapping. In case of large-scale mapping the simultaneous field description of actual vegetation and interpretation of satellite images and aerophotographs is necessary.

Acknowledgements

This paper is written with high respect to these people who took part in the large-scale mapping of Estonian vegetation but whose work due to political situation never got known outside republic but what is an outstanding starting point to continue the investigation the diversity of Estonia nature.

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RENTED OR OWNED LAND – IMPLICATIONS FOR LAND ABANDONMENT

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Abstract

The use of rented land has increased steadily over time in Northern Norway. At the same time there is a common perception that there is an increased re-growth of agricultural land. In this paper we investigate if the use of rented land also is a factor that leads to increased re-growth. We utilize land use data from the 3Q project in Northern Norway. These data are combined with data from the applications for acreage support to divide areas on tree types of properties. The area of abandoned land is explained as a function of property types. Our results show that there is a significant difference between owner used and rented land with respect to the amount of abandoned land on the property. This suggests that when previous farmers have rented out their land, one third of the previously farmed land may have been taken out of productions, and is now identified as abandoned land.

1 Introduction

The size of farm operations are increasing in Norway to enable better utilizations of new technologies and provide higher net farm incomes. Thus the use of rented land in Norway has increased steadily over time. In 1999 the rented land constituted 35 percent of the farmed land in Northern Norway, and this increased to 47 percent in 2006 (see Puschmann & Stokstad 2010). A common perception is that that there is an increased re-growth of agricultural land in some areas. Thus is it interesting to see whether the use of rented land is a factor that leads to increased re-growth.

The study area is the three northernmost counties, Nordland, Troms, and Finnmark of Norway, where grass production is the main crop production. Farm properties particularly along the coast in Northern Norway are generally small. Many of these small properties used to be farms where the family survived on fishery and subsistence farming. Today the holdings with active farms are made up of the larger farm properties. However the farm structure from the sixties can to a large extent be seen from the present property structure of rented land. For example the average size of a farm property that was rented out both in 1999 and 2006 was less than 3 hectares, while the property belonging to an active farm in both years where about 20 hectare (Puschmann & Stokstad 2010).

The questions investigated in this paper are: (1) who owns the abandoned land, and (2) are we able to explain the share of abandoned land by whether the area it is owned by the farmer or rented land?

2 Material and methods

This study is based on land cover data from «3Q». This is a program which is initiated to document state and changes in Norwegian agricultural landscapes (see Dramstad et al. 2003) for further information about the data source). Land cover and land use are determined by interpretation of aerial photographs from year 2000, however some exception occur. We have also used information from the «digitised property records» (DEK) to identify which property the area belongs to. Based on the information in the applications for acreage support in 1999 have we divided theses properties in three groups:

1. Own land: These are properties that are tied to the applicants of agricultural support payments as the main property in 1999. This is mainly area own by the farmer that apply for subsides, alternatively it is where the active farmer lives and/or where the animals are kept during the winter.
2. Rented land: These are areas that are part of properties that active farmers have registered that they do use/rent land from.
3. No use: Areas that is part of properties that no one applied for acreage support for in 1999.

In this study are we using the data from the 3Q squares about the open areas with farmed or potentially previously famed land which we define as abandoned land. Farmed land includes land used for grass or grain production, horticulture and pasture (A1, A2 and A3 in 3Q). Abandoned land is defined as area in «uncertain agricultural use» and «uncultivated grass land» (this is land cover type A4 and F1 in 3Q). Figure 1 shows the sum of area of the four land use/cover groups when the total area are also is divided on the three types of properties.

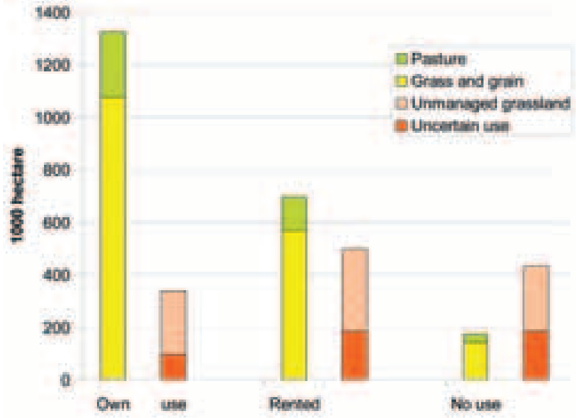

Figure 1: The total area of farmed land (pasture and grass and grain) and abandoned land (unmanaged grass land and uncertain use) divided on the three types of property status, own land, rented land and land which no one apply for acreage subsidy for labelled «no use».

The data sample consists of 157 squares, each 1km X1 km. Total area of interest on each square is the sum of farmed land and abandoned land. We want to test to what extent we can explain the area of abandoned land (Y) per square as a function of how much land that is own land (X_{own}), rented land (X_{rent})and land in no use ($X_{no\ use}$). The tendency to re-growth on these three types of land are compared by estimating the share of «uncultivated grassland» and «pastures and hay meadows that may not longer be in use» of cultivated land as a function of whether the area is in use by the owner, rented land or not receives any acreage support.

$$Y=\beta^0 + \beta^{own}X_{own} + \beta^{rent}X_{rent} + \beta^{no\ use} X_{no\ use} +e$$

Total open area (Q) is defined as the sum of the area of the three property types of land. By dividing this equation with Q on both sides, we obtain an expression which is better suited to directly look at the difference between own land and rented land as well as own land and land not in use. Thus in the equation below y refers to share of total area that is abandoned land and x_i refers to share of area of property type i. The estimated model is:

Equation 1: $y= \beta^{own} + \beta^0 (1/Q) + \beta^r x_{rent} + \beta^n x_{no\ use}$

where $\beta^r = + \beta^{rent}-\beta^{own}$ and $\beta^n = \beta^{no\ use} -\beta^{own}$

The value of ^{r} will indicate whether there is a significant difference between abandoned land an rented land compared to own land since it measures the difference between own and rented land. The same applies for β^n and the area in the «no use» group.

3 Results

Table 1 shows he parameter estimates and standard deviation for the parameter estimates for the model estimated on the total sample and for the three counties separately. With this simple model, adjusted R^2 is 0,65 i.e. we explain 0,65 percent of the variation in the share of area with abandoned land with the model. Table 1 also shows that the parameter estimates for the difference between own land and rented land and land not in use are quite similar in the three county models. To test whether there are significant differences between the regional model and the total model the county models are estimated with the restrictions that the parameter estimates are identical to the total model. The F-tests in table 1 indicates that we do not find significant differences between the county models and the total model.

Table 1: Coefficients, standard deviation and adjusted R^2 for the total data sample and the different counties. The last line shows the F-test for a test of whether the coefficients in the county model is identical to the coefficients in the total model.

Number of observations		**All of North Norway**	**Nordland**	**Troms**	**Finnmark**
		157	80	58	19
Abandoned area, «dekar» pr 1*1 km	Value ^{0}	2,19	1,23	8,994	4,65
	St. dev	(0,70)	(0,75)	(4,94)	(1,77)
Share abandoned area (when the land is in use by owner)	Value β^{rown}	0,15	0,16	0,11	0,07
	St. dev	(0,03)	(0,03)	(0,07)	(0,09)
Difference between owned and rented land – share of area with abandoned land	Value β^{r}	0,31	0,30	0,31	0,33
	St.dev	(0,05)	(0,06)	(0,10)	(0,16)
Difference between owned and land not in use – share of area with abandoned land	Value β^{n}	0,69	0,73	0,63	0,70
	St. dev	(0,05	(0,06)	(0,09)	(0,14)
Adjusted R^2		0,65	0,70	0,51	0,76
F test for the restriction that the regional model differs from the total model.			0,55	0,54	0,82

Table 1 shows that there is a significant difference between owner used and rented land. Hence when previous farmers rent out their land, we may expect more re-growth. However this is not as serious with respect to re-growth as when the land not is taken in use by remaining active farmers.

The coefficient β^0 can be interpreted as the area of abandoned land which is independent of property type. This is measured in 0,1 hectares («1 dekar»). The area is significantly different from zero, but is it a small area. If the open land makes up 10 % of the 3Q square, this area would be about 2 percent of the acreage. In addition there is always 15 percent of the total open land that is abandoned.

If the land is rented, this increases with 0,31 percent alternatively 0,69 percent if the land not registered as in use. This percentage refers to the area of total open land. If we have 100 hectares of own open land – we expect to find (15 + 2) percent abandoned land. That is 83 hectares farmed land. However if the property is rented out we expect to find: 15+2+31=47 hectares abandoned land, that is 53 hectares farmed land. These numbers suggest that when properties are rented out, slightly more than one out of three hectares becomes abandoned land. For land not in use, the famed land would be about 15 hectares, or less than 1 out of 5 hectares would be farmed.

4 Discussion

One shortcoming with the classification of areas is that the majority of the photos are from 2000, mainly taken in July and August, and a few photos about 10 percent, are form the spring of 2001. Spring photos will to a large extent reflect the management in the previous year since grass is the most common crop in this area. Any change in rental agreements between 1999 and 2000 will therefore be a source of error in the classification of the property. The most likely error to occur is that we have land that is classified as in use by owner that is either out of use or rented out, and that we have areas classified as rented land that in realty should be classified as out of use when the photo was taken. However, we expect this potential classification error to be limited since the majority of the areas keep their status with respect to property type also in 2005.

We anticipate that it is the more marginal areas that goes out of production first, thus some difference between own and rented land is natural. However, the area of abandoned land is very likely to underestimate the area which has gone out of production. When an area not is used as grazing fields or winter feed production, the area will eventually be reforested. When an area has more than 75 percent bushes and trees, it will not be classified as a forested area within a 3Q square.

The rental prices of land in Northern Norway are low and will also in some cases be zero. Moreover, many rental agreements are short term and informal. Thus neither the renter nor the owner of the land will find it profitable to undertake major investment as new ditches or to maintain old drainage. Consequently, these areas will cease to be used as it does not withstand the use of newer heavy machinery. More efficient and heavy machinery is therefore likely to make parts of the rented land less attractive for agricultural purposes. In turn that further limits the time frame in which current rented land will remain as rented land.

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MODELLING LANDSCAPE REGIONS ON A REGULAR GRID USING BINARY LOGISTIC REGRESSION

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Abstract

The change from one landscape to another is gradual. Landscape classes can therefore be considered as theoretical concepts and a particular location or area can be affiliated with a number of different landscape classes. Landscape classification thus becomes a statistical and probabilistic exercise. Such a probabilistic approach to landscape regions can be made operational using a grid model combined with binary logistic regression. This approach was tested on a landscape region in Norway.

Figure 1: The landscape region Forest landscapes of southern Norway (Puschmann et al 1999).

1 Material

The standard Norwegian statistical grid SSB5KM (Strand & Bloch 2009) with quadratic grid cells of 25 km^2 (5 × 5 km) was used as the spatial framework for the study. SSB5KM covers Norway and adjacent sea areas and consists of 19 455 grid cells. The grid is a suitable starting point for modeling because the spatial units are uniform with respect to size and shape. The size of 5x5 km grid cells was arbitrary, justified by subjective judgment and interpretation of what size best would capture the landscape elements and variation.

The landscape region Forest landscapes of southern Norway (Puschmann et al. 1999) was used as the test case (Figure 1). The landscape region was represented in grid format by encoding the grid cell as 1 if the «Forest landscapes of southern Norway» was present in the grid cell, otherwise to 0. Sixteen independent or explanatory variables were also used in the model. These were purposively selected in order to represent as closely as possible the factors forming the basis for the Norwegian reference system for landscapes (Puschmann 1998, 2005). The variables were compiled from a number of sources and represented as a vector x_k {kl1..16} attached to each grid cell in SSB5KM.

The first independent variable was x_1 northing (measured as kilometer coordinates in UTM-33/WGS84(EUREF89)). Easting was not used in the model due to Norways placement diagonally across several longitudes. Topography was captured with two variables. Maximum elevation (meters) above sea level (x_2) and relief (x_3) measured as difference (in meters) between highest and lowest elevation above sea level. Both datasets were obtained from the national digital elevation model interpolated to a 100 × 100 meter grid from 20 meter contour lines. Maximum elevation and relief for each grid cell were computed from the points falling inside each SSB5KM grid cell.

Distance to the coast x_4 was measured in kilometer from the center of each grid cell to the nearest point on the Norwegian coastline (including islands). For grid cells containing sea area, the distance to the coast line was set to 0 irrespective of whether the centerpoint was on land or not. The reference data set was the digital version of the national topographic map (scale 1: 50,000).

Different aspects of land cover and land use were captured by variables x_5 through x_9. All of these variables were compiled from the digital land resource map AR5 (scale 1: 5,000) and measured as fractions. The variables were (x_5) agricultural land, (x_6) infield pasture (x_7) forest land (x_8) inland water bodies (below the tree line) and (x_9) area above the tree line.

Human impact was captured by (x_{10}) total ground area of buildings, measured in square meters and (x_{11}) total population of each grid cell. These data were obtained from the national register of buildings (GAB) and from the national census provided by Statistics Norway.

The six remaining variables described the farming systems. These were percentage of the agricultural area used for production of cereal (x_{12}) and grass(x_{13}). The livestock was represented by number of cattle (x_{14}) and sheep (x_{15}). Finally, the number of summer farms (x_{16}) in each grid cell was recorded. Data was obtained from the national register of applications for agricultural subsidies and from the national register of buildings (GAB).

2 Method

Binary logistic regression was used to model the landscape region. The binary logistic regression equation

$$P(Y)=\frac{1}{1+e^{-(b_0+b_1x_1+b_2x_2+...+b_mx_m)}}$$

calculates the probability of a binary variable Y occurring. The presence or absence of «Forest landscapes of southern Norway» is an example of such a binary variable. Furthermore in the equation, *e* is the base of the natural logarithms. x_1 through x_m are the variables used to calculate P(Y) and b_1 through b_m are the coefficients attached to each predictor. Finally, b_0 is a constant.

Maximum-likelihood estimation applied with SPSS® was used to estimate the coefficients b_0 through b_{16}. With the coefficients established, the regression model was run, also using SPSS®, and the probabilities P(Y) calculated for each grid cell in the spatial model. The results were attached to each grid cell *i* in SSB5KM yielding a probability map of «Forest landscapes of southern Norway».

3 Results

The results are shown in Figure 2. The figure shows the calculated probabilities for being part of the «Forest landscapes of southern Norway». Notice how the high probabilities coincide with the original interpretation of this landscape region (Figure 1) and how the probability gradually diminishes away from this core area, but in most directions without any abrupt edges.

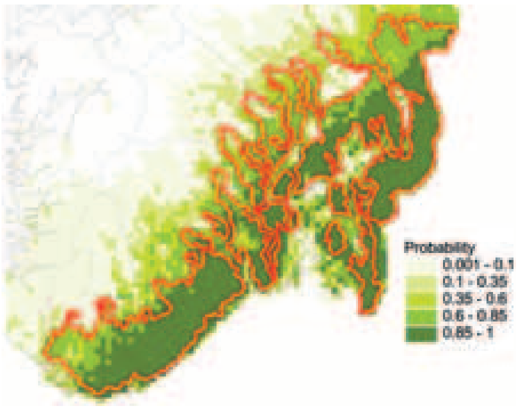

Figure 2: Modelled probability of finding the landscape region «Forest landscapes of southern Norway».

Figure 3 is a result of a comparison with similar exercises carried out for all other landscape regions in the region. The green grid cells are those where «Forest landscapes of southern Norway» is the most likely landscape region according to the probability model. The original interpretation of this landscape region (from Figure 1) is drawn as a red border. The figure illustrates the correspondence between the original, cartographic delineation of the landscape region and the result of the statistical method.

Figure 3: The landscape region «Forest landscapes of southern Norway» by cartographic interpretation (solid red line) and statistical modeling (green area).

Discussion

The logistic regression model predicts the landscape region with variable accuracy (Figure 3). The statistical result is not necessarily «better» than the traditional cartographic approach, but it is useful in pinpointing the problems and limitations of the model as well as of the reference data set. Comparison of the two maps can help improve the understanding of both results.

The probabilistic approach shows that the landscape regions of the reference data set does represent distinct arrangements of landscape features but that boundaries drawn between the regions will be ambiguous.

The probabilistic landscape model has deficits linked to the model itself, the data used in the model and the complexity of the results represented as a series of data layers instead of a single map. The results are, however, useful in as much as they explain limitations and draws attention to shortcomings in the reference data set. The probabilistic model also has its limitations due to shortcomings in input data as well as inability to fully represent the complexity of the landscape characteristics. It will not replace the regional approach to landscape classification, but can be used as a valuable supplement in landscape studies.

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THE NORWEGIAN AREA FRAME SURVEY OF LAND RESOURCES: AR18×18

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Abstract

AR18×18 is an area frame survey of land resources in Norway, methodologically linked to the *Lucas* survey carried out by Eurostat (Eurostat 2003). The purpose of the survey is to establish an unbiased and accurate land cover and land use statistic providing a description of the state of land resources in Norway. The survey will also provide a baseline for future reports regarding changes in land resources – a national land resource accounting system.

AR18×18 is based on *Lucas* (Land use/cover agricultural survey), a European area frame survey carried out in the EU countries by Eurostat. The sampling units of *Lucas* are points located on the intersections of an 18 × 18 kilometer grid mesh throughout Europe. Each of these points is the centre of a Primary Statistical Unit (PSU) of 1500 × 600 meters. The *Lucas* survey is carried out on ten sample points scattered within each PSU. The Norwegian modification of *Lucas* is to add a land cover survey of the whole PSU following the Norwegian system for vegetation and land cover mapping at intermediate scale (1: 20,000).

Operational experience with the AR18×18 method was gained during the first pilot phase in 2004 and 2005. These experiences led to adjustments of the method and also provided the basis for a preliminary evaluation. The overall assessment is that the *Lucas* survey methodology works well, while the *Lucas* measurements have shortcomings regarding the definitions and detailed instructions for how measurements should be carried out. This is in particular the case for *land use* measurements, landscape *photography,* natural *hazards* and registration of *linear features* along transects. In AR18×18, the system is improved by adding land cover mapping of the entire PSU. This is a necessary adjustment in order to create a practical and functional survey addressing the needs for land resource statistics in Norway.

The AR18×18 sampling method, based on *Lucas*, is statistically sound and efficient. The systematic sample strategy ensures that the sample is spread out as much as possible, thus creating a representative replica of the population and covering maximum variability. The simplicity of the method also leads to high flexibility. Statistics can easily be prepared for any regional subset of the data. It is observed that the AR18×18 easily can be extended to by densification (e.g. using a 9×9 kilometer grid). This will improve the precision of the estimates and is in particular useful when the goal is to provide statistics for smaller regions.

Land use and land cover types that cover very small areas will not be recorded by the land cover mapping method used in AR18×18. This is a question of detectability and the problem is related to the method of measurement, although some times falsely attributed to the sampling method. The challenge is to design appropriate observation methods to cover these features while keeping the workload of the field crew at an acceptable level and within a realistic budget. Uncommon or even rare phenomena will also be detected and recorded as long as the occurrence is spatially random. Problems arise when the spatial distribution of rare features is strongly autocorrelated.

In situ assessment is an essential part of the AR18×18 methoydology. Reliable land use and land cover assessments outside the built-up and agricultural land is not possible from aerial photo interpretation alone. The Norwegian Forest and Landscape Institute is conducting the AR18×18 survey on a national scale over a period of approximately ten years. Progress will depend on available resources but the completion of the survey is expected in 2015.

1 Background

The only feasible approach to survey land resources on a national scale – including mountain areas – in Norway is to use statistical sampling. An ordinary survey is simply too expensive. The area extent of the conterminous Norway is approximately 324,000 km^2. A complete land cover survey will cost more than NOK 1 billion, even when the amount of details is kept at a moderate level. A realistic budget for a highly detailed survey is even higher, around NOK 5 billion. A statistical area frame survey, on the other hand, can be carried out on a budget around NOK 8–10 million. The sampling based survey can also be repeated at fixed intervals in order to provide information about changes in land resources.

AR18×18 is an area frame survey of land resources in Norway, methodologically linked to the *Lucas* survey carried out by Eurostat (Eurostat 2003). The purpose of AR18×18 is to establish an unbiased and fairly accurate land cover and land use statistic providing a description of the state of land resources in Norway. The study will also provide a baseline for future surveillance of changes in land resources.

AR18×18 is implemented by the Norwegian Forest and Landscape Institute. Statistics Norway (SSB) has participated in the development of the approach and the adaptation of the *Lucas* methodology to Norwegian conditions and needs.

The method was first tested in the mountains of Hedmark County, in a field survey carried out during the summer season of 2004 (Rekdal & Strand 2005). The field survey has been extended to full coverage of twelve counties (50 % of the land surface) by the end of 2009.

2 Survey method

AR18×18 is based on *Lucas* (Land use/cover agricultural survey), a European area frame survey carried out in the EU countries by Eurostat (Eurostat 2003). The sampling units of *Lucas* are points located on the intersections of an 18 × 18 kilometer grid mesh throughout Europe. Each of these points is the centre of a Primary Statistical Unit (PSU) of 1500 × 600 meters. Ten additional points, known as Secondary Statistical Units (SSU), are located inside each PSU (Figure 1). Measurements in *Lucas* are mostly made on an approximately 7 m^2 plot around each SSU and on a transect through the five northernmost SSUs of each PSU.

Figure 1: A Lucas sampling site consists of a Primary Statistical Unit (PSU) shaped as a 1500 × 600 meter rectangle. Ten Secondary Statistical Unites (SSU) are located inside the PSU. The distance between the SSU's is 300 meter.

AR18×18 is using the Lucas concept of PSU and SSU locations. The major modification is that AR18×18 also collects land cover data for the rectangular PSU covering 1500 × 600 meter (0.9 km^2). The PSU provides a better coverage of the area in the data collection and improves the probability for inclusion of rare features. It also allows the survey to be treated as a single stage systematic sample instead of a two-stage sample.

A PSU is included in the survey as long as any part of it falls within Norwegian land areas (including freshwater). The estimated total number of sampling sites in the survey is 1083, but the actual number may change slightly as PSUs along the complex coastline of western- and northern Norway remains to be studied in detail.

3 Survey locations

A field map of each survey site is prepared using topographical maps provided by the Norwegian Mapping Authority (Statens kartverk). The map consists of a detailed image of the PSU and its immediate surroundings (based on topographical map in scale 1: 50,000) and an access map (based on topographical map in scale 1: 250,000). Key information including the site identification, name of the municipality and the coordinates of the center point is also included.

Coordinates for all PSUs and SSUs in the survey has been generated and entered into computer files. The coordinates are uploaded from these files into handheld GPS receivers used by the crew to locate the SSUs in the field.

GPS equipped with external antenna is used in forest areas where reception is known to be difficult. Detailed instructions for approach to the SSUs are provided in the survey guidelines. These guidelines also regulate behavior in cases where GPS reception is failing. Special attention is given to the fact that Norwegian mountain terrain may lead to significant deterioration of GPS signals due to echo effects.

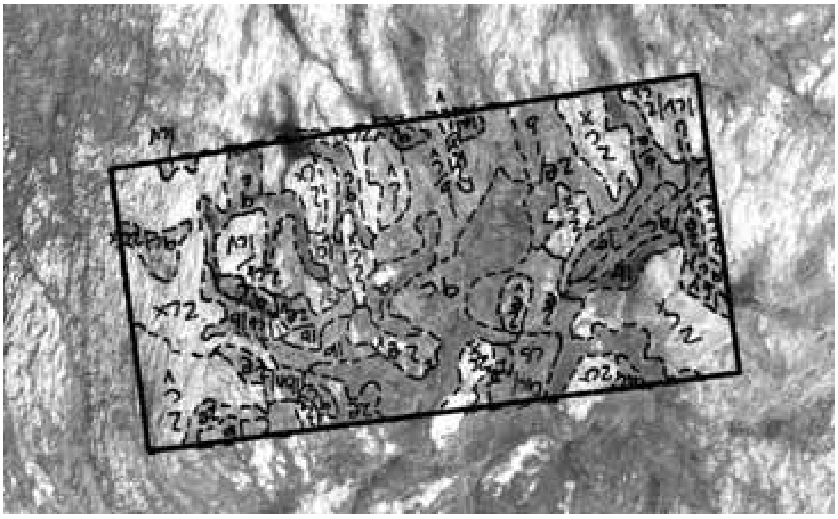
Figure 2: Aerial photograph with land cover interpretation (Site 2028, Kvikne, Tynset).

4 Land cover survey

The land cover survey of the PSUs is carried out following Forest and landscape's system for vegetation and land cover mapping at intermediate scale (1: 20,000). The system is developed through mapping projects throughout Norway over a period of 25 years (Rekdal & Larsson 2005). The system is thoroughly tested, the cost is acceptable and the results are used for quantification and assessment of many aspects of land resources.

The basic nomenclature of the system for vegetation and land cover mapping consists of 54 land types (45 of these are vegetation types). A number of additional registrations are added to these basic observations. Examples are rock outcrops, coverage percentage of lichen, willow or fern and areas with particularly rich grass cover. There is close coherence between this mapping system and a classification system often used for detailed vegetation descriptions in Norway (Fremstad 1997). The differences are mainly that the approach used by Forest and Landsacape is less detailed for vegetation types that cover small areas or require highly specialized botanical knowledge for identification. The hierarchical sequence of key registrations in the two systems is also somewhat different because the Forest and Landscape system is aiming to be efficient during applied mapping in the field.

Vegetation and land cover mapping following the Forest and Landscape system is carried out in the field using aerial photographs usually at scale 1: 40 000. Both black and white and IR photos can be used, but IR photos are preferred if available. Vegetation polygons are drawn directly on the photos (Figure 2) and later digitized and processed using GIS software.

The minimum polygon size is 0,1 haa, but a mosaic of two different vegetation types can be registered for a polygon when each type covers at least 25 % of the area. The dominant vegetation type is for statistical purposes counted as covering on average 62,5 % of each polygon, while the secondary vegetation type is counted for the remaining 37,5 %. A simplified vegetation map based on the measurements from Figure 2 is shown in Figure 3.

5 Statistical considerations

The area frame survey is a systematic random sample. The systematic element is that a location is surveyed for every 18 kilometer along the grid mesh. The random element is that the starting point of the grid is located randomly. This sampling strategy is in reality a *cluster sample* consisting of a single cluster, but where every element of this cluster is included in the sample.

It is possible to construct 360 different systematic samples based on the chosen survey strategy: Each of the survey locations is 0,9 km^2 (1500×600 meters), the locations are interspaced with 18 kilometers in both directions and $18^2/0,9 = 360$. The sampling frame thus consists of 360 clusters, each containing a national coverage of equally interspaced sampling locations. By choosing a random starting location, one of these clusters is selected and all the locations in that particular cluster is included in the survey.

The systematic random sample is particularly efficient for geographical surveys because it avoids selection of elements located close together (Thompson 2002). Geographical phenomena, including land resources and related features, are usually autocorrelated. Autocorrelation is the effect that places located close to each other tend to be more similar than places located further away from

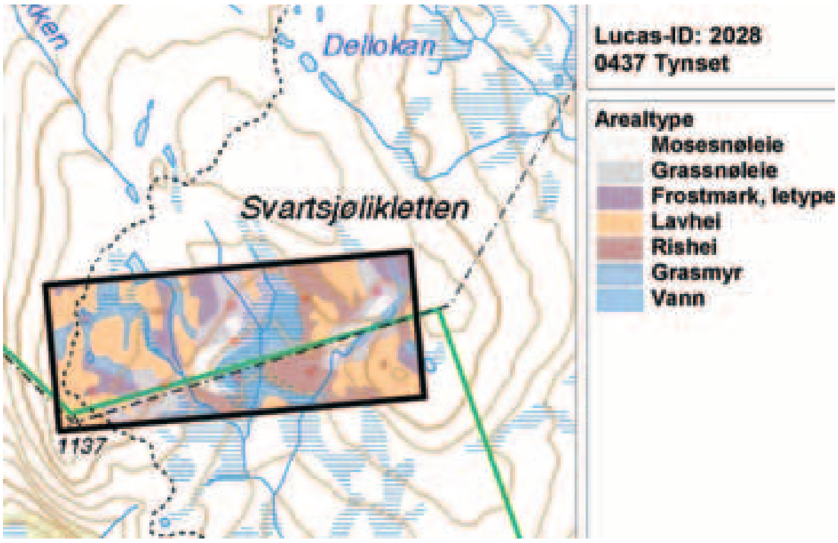

Figure 3: Simplified land cover map (Site 2028, Kvikne, Tynset). [Base map: N50 Rasterdata, Statens kartverk. Topographic map © Norge digitalt.

each other. The systematic sampling strategy ensures that the variance in the cluster is as high as possible while the variance between the clusters is as small as possible. This implies that the likelihood that the sample represents the full variability of the population is maximized.

To profit from this strategy, it is important to include all the elements of the cluster in the sample. The practical implication is that every location that includes part of the population should be included in the sample. Field mapping units partly located in Sweden or including a substantial area of ocean are all included when they also contain part of the Norwegian land area although only the part falling inside Norway is actually mapped. The rule also applies when the area frame survey is used to estimate land resources for smaller regions. Every field mapping unit containing a part of the said region should be included in the sample.

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HABITAT MODELING AND THE LINK BETWEEN LANDSCAPE PATTERN AND BIODIVERSITY PROCESSES

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Abstract

Habitat fragmentation is often counteracted by linking remaining habitat patches with corridors or stepping stone habitat patches. The underlying assumption is that organism movement between habitat patches, i.e., functional connectivity, can be predicted from present habitat configuration, i.e., structural connectivity. However, landscapes themselves are dynamic, so that transient dynamics may be more prevalent than equilibrium conditions assumed by relevant ecological theories. In addition, these theories rely on island models that may not apply to terrestrial mosaic landscapes where matrix resistance may vary between habitat types. The link between structural and functional connectivity is fundamental to the application of habitat maps for conservation, but is based on little empirical evidence, and recent studies suggest that commonly used models may not appropriately predict landscape effects on biodiversity processes. In summary, while habitat maps invite a static view, their successful application for conservation requires thinking in terms of spatio-temporal processes and their interactions, which are difficult to observe and visualize.

1 Sensitivity of habitat modeling to the input map

Predictions of the biological response to changes in land use or climate typically rely on habitat modeling. Habitat modeling refers to the predictive modeling of the distribution of species or communities from empirical occurrence data and the spatial distribution of environmental factors or resources. The choice of statistical modeling techniques has received much attention following a seminal paper by Guisan & Zimmermann (2000), and data availability may often drive the decision which ecological processes are reflected in the model. However, model specification also implies a choice among ecological paradigms, reflecting important assumptions about inter-specific interactions and the role of space. For instance, modeling the distributions of individual species is only meaningful if mutualistic interactions are deemed unimportant. Alternatively, one would need to model species assemblages. Similarly, predicting occurrence from local site conditions alone is compatible with the classic view that ‘everything is everywhere and the environment selects’, but ignores the possibility that dispersal processes may limit distributions. Alternatively, habitat modeling would need to explicitly consider landscape connectivity.

Table 1: Map representations corresponding to different landscape models imply different data types and suitable methods of spatial analysis.

Landscape model	Data type	Methods
Patch – Matrix	binary: black and white map polygons	connectivity, percolation network analysis
Mosaic	categorical: multi-state mosaic polygons or grids	landscape metrics
Gradients	multivariate quantitative: continuous data fields grids	geostatistics edge detection gradient analysis fractal dimension

The choice of input map has important consequences for habitat modeling (Table 1). Models based on an individualistic species concept are most compatible with modeling environmental gradients using data such as solar radiation or NDVI derived from DEM, satellite imagery, or other GIS data. Studies in a spatial paradigm often reduce a mosaic-type land cover map to a binary map showing patches of suitable habitat for the organisms of interest in an inhospitable matrix. These choices imply differences in data type and thus require different suits of methods of spatial analysis (Bolliger et al. 2007).

Spatial statistics are sensitive to the grain or spatial resolution of the data. Landscape metrics, which are used for quantifying spatial pattern from a binary or nominal grid map, typically are sensitive to spatial resolution, the level of detail with which patch edges are digitized, and map boundary effects (Wu 2004). The latter may also affect the assessment of connectivity of a habitat network based on graph theory. A good habitat map thus should (*i*) map cover types that correspond closely to species' habitat requirements and can be used to assign matrix resistance values as a function of cover types, (*ii*) cover a map extent that adequately reflects the mobility of the organism, (*iii*) provide a spatial resolution that corresponds to the resolution at which the organism responds to the environment, (*iv*) provide meta data including information on source data and time of acquisition and uncertainty or mapping error, and (*v*) be directly comparable to data from other time steps to facilitate assessment of the dynamics of populations, communities, and landscapes.

2 Causes and consequences of landscape dynamics

While maps suggest a static view, vegetation and landscapes rarely are constant but undergo changes driven by natural processes, such as succession, and anthropogenic land-use change both during initial conversion of natural systems and adaptation of land-use patterns to changing economic conditions in cultural landscapes. It is not enough, however, to monitor vegetation and landscape change, because the underlying mechanisms, or drivers of landscape change, are themselves subject to change.

For instance, calcareous grasslands in Southeastern Germany, originated in medieval times when marginal areas, such as steep slopes, were cleared for communal grazing. High demand for wool namely in France led to a regional grazing system (transhumance) where large herd of sheep would spend winter e.g. in milder climates in Southwestern Germany and during summer were herded through large areas in Southeastern Germany. After the collapse of the wool market around 1900, rotational sheep grazing was maintained in some areas, until the opening of the Eastern border in 1989 lead to a collapse of the meat market. Today, European Common Agricultural Policy dictates the economic conditions for the continuation of rotational sheep grazing systems and thus for the maintenance of calcareous grasslands, which provide important habitat to many species and are of high conservation value (Bender et al. 2005).

As ecological systems may require a long time to adjust to changing drivers, transient dynamics may be the norm, whereas dynamic equilibrium conditions that are inherent to most ecological theories about biodiversity may rarely apply.

3 How landscape pattern affects biodiversity – in theory

Various ecological theories make predictions regarding the effect of landscape pattern on biodiversity processes and the resulting patterns of species occurrence (metapopulation theory, Levins 1969), species diversity (theory of island biogeography by MacArthur & Wilson 1976, unified neutral theory of biodiversity and biogeography by Hubbell 2001), or intra-specific genetic diversity (population genetics, Wright 1968,1969,1977,1978) within local populations. In summary, these theories maintain that connectivity avoids negative effects of isolation on biodiversity. A lack of connectivity results in reduced immigration of species, individuals, and alleles into local populations and communities, which results in a lower local species richness (alpha diversity), fewer local populations, and a smaller number of alleles in local populations.

These theories are mostly based on island models where the landscape is conceived to consist of homogeneous patches of habitat of equal quality surrounded by a uniformly inhospitable matrix, like islands in an ocean. Terrestrial landscapes, however, deviate from this model as matrix resistance may vary between different land cover types subsumed that together form the matrix, each of these cover types will itself provide habitat to some species, and the pattern of land use and land cover may change over time. While these complications violate key assumptions of the above theories, they may have important consequences for connectivity.

Landscape connectivity has been defined as the interaction between organism movement behavior and landscape structure (Merriam 1984). While the structural component can be quantified from land cover or habitat maps relatively easily (see above), the functional component in terms of the individual behavioral response of organisms to landscape structure (observed by telemetry or trapping) or of gene flow resulting from movement behavior (inferred from population genetic structure) are much more difficult and costly to assess (Brooks 2003).

Since the 1980s, conservation management has increasingly incorporated the concept of enhancing connectivity as a conservation strategy to maintain biodiversity within fragmented landscapes. While the idea is intuitively convincing and politically successful, its early applications are based on surprisingly little empirical evidence (Harrison & Bruna 1999). Available evidence suggests that landscape structure does matter, but that insights from theoretical work such as percolation thresholds derived from the simulation of neutral landscapes may not be directly transferred to real-world situations. Empirical tests are therefore needed before we can safely infer from landscape structural connectivity to functional connectivity.

4 Testing the link between landscape pattern and biodiversity processes

In a recent review of the effects of landscape modification and habitat fragmentation on biodiversity, Fischer & Lindenmayer (2007) identified the following research priorities: (1) quantifying species dispersal through a combination of field, modeling, and genetic techniques; (2) focusing on plants and invertebrates to overcome a bias towards birds and mammals; (3) investigating biodiversity patterns over entire modified landscapes; (4) predicting cascading effects of landscape modification through scenario simulation; (5) using natural experiments to study effects over larger spatial and temporal scales; and (6) linking ecological research with interdisciplinary approaches, conservation policy, and management. This section discusses insights gained by addressing some of these issues in the context of calcareous grasslands in Southeastern Germany and Northern Switzerland.

Small, isolated calcareous grasslands in Northern Switzerland showed effects of isolation, but in different ways than expected (Schlup 2009). Compared to larger and better connected patches, they did not differ in within-patch species richness (alpha diversity) when sampled in a comparable way, but showed increased species turnover among patches (beta diversity), i.e., higher differentiation among sites. This effect was most pronounced for plant species characteristic of calcareous grasslands and species whose seeds lack adaptation for wind dispersal.

A seed release experiment showed that common assumptions on wind dispersal may not hold for the majority of plant species characteristic of calcareous grasslands (Bolli 2009). Seeds released at vegetation height (80 cm) were dispersed with a frequency related to seed terminal velocity and with a distance distribution according to the expected negative exponential dispersal function. Seeds released within the vegetation (40 cm), the typical situation for most forbs in this system, were dispersed in much lower numbers, but when they did get dispersed, the capture rate was independent of distance (1 m , 2 m, or 5 m from release station) and of terminal velocity of the seed.

The evaluation of a 20-year landscape modification project aimed at improving and reconnecting calcareous grassland patches in Southeastern Germany, based on extensive baseline data, showed numerous colonization events in newly grazed patches (Lehnert 2008). This indicates that, rather than wind, sheep are an important dispersal vector in this system.

Collectively, these and related examples suggest that commonly used models may not appropriately predict landscape effects on biodiversity processes.

5 Conclusions

Maps of vegetation or of land-use and land cover types are of fundamental importance for landscape-scale conservation planning. However, we need to overcome the static view implied by maps. Successful application for conservation requires thinking in terms of spatio-temporal processes and their interactions. These are both difficult to observe and to visualize.

In the context of land-use change and habitat fragmentation, it is important to realize that we can't take the link between landscape pattern and biodiversity processes for granted. The predictions of ecological theories rely on assumptions relating to the nature of the intervening matrix, the absence of landscape change, and the reaching of a dynamic equilibrium between processes, all of which are likely to be violated to important degrees in landscapes undergoing land use change.

In order to make realistic predictions of the biological response to climate change, distribution modeling under scenarios of climate change will need to consider to what degree mutualistic interactions and dispersal may constrain the spread of species and communities. Compared to models based on species-specific climate envelopes alone, these effects may lead to considerable temporal lags or completely different trajectories.

Acknowledgments

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MAPS FOR MONITORING LONG-TERM CHANGES TO VEGETATION STRUCTURE AND COMPOSITION, TOOLIK LAKE, ALASKA

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Introduction

The Toolik-Arctic Geobotanical Atlas (http: // www.arcticatlas.org/) includes maps at seven scales from small plots to the circumpolar Arctic. Maps at the finest scale are intended to monitor long-term changes to the plant communities on two different-age glacial surfaces near the Toolik Field Station in northern Alaska. This poster presents the methods, example maps from the plots of the Toolik Grid, which is on the younger (late Pleistocene) glacial surface. Results from four repeat samplings of the Toolik and Imnavait Creek grids at 6-year intervals from 1989 to 2008 demonstrate the value of the data set for monitoring long-term changes in this Arctic landscape.

Method

Permanent 1 x 1-m plots were sampled in 1990 to establish a baseline for monitoring changes to the vegetation at 85 grid points of the 1.2 x 1.1-km Toolik Lake Grid (Figure 1) (Walker and Maier 2008). A similar grid with 72 grid points was sampled in the nearby Imavait Creek watershed. The grid points are spaced 100 meters apart. Each 1-m2 plot was located in a random direction from the grid stake within 2 m of the grid point stake and in the same vegetation type as at the stake. An aluminum point-quadrat frame was used for the sampling (Figure 2). A methodology developed for the International Tundra Experiment (ITEX) permits near-exact repositioning of the frame for long-term monitoring (Walker 1996). The plots are being monitored every 6 years using the same methods.

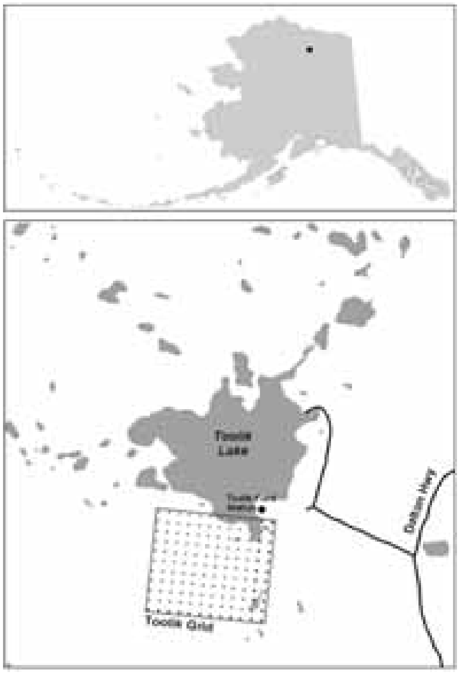

Figure 1: Top: Location of the study area within Alaska. Bottom: Location of the Toolik Grid within the Toolik Lake area. Red grid points are those that are included in the sampled data.

Figure 2: (Left) Point quadrat used in sampling. The vertical legs are positioned in metal guides that are nailed into the tundra. The frame can be repositioned exactly in successive sampling years by leveling the frame, clamping it securely, and aligning it to a set of metal registration points that are nailed into the tundra at 4 grid points (black «X» in the species plots in Figure 3). (Right) Two parallel grids of monofilament line, one above the other, are spaced 2 cm apart. Aligning the intersection points in both grids permits unambiguous identification of points in the plant canopy. We recorded the species at the top and bottom of the plant canopy at each point and the distance from the bottom monofilament line to the top and bottom species.

Results

The example (Figure 3) displays the canopy height, topography of the ground layer, and species recorded at 100 points in a 1 x 1-m plot.

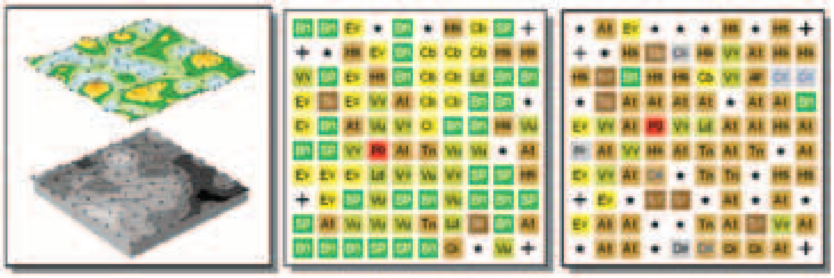

Figure 3: (Left) Maps of the plant canopy and ground surface topography of a 1 x 1-m sample plot. (Middle) Species at 10-cm intervals in the overstory. (Right) Species at 10-cm intervals in the understory. The color of the small squares correspond to plant growth forms (dark green, low shrubs; light green, erect dwarf shrubs; yellow, graminoids; red, forbs; light brown, non-Sphagnoid bryophytes; dark brown, Sphagnoid byophytes; gray, lichens), White boxes with symbols are non-plant occurrences: stars, litter; black «X», registration points for alignment of the grid. The letter codes in each box are first letters of the Genus and species names of the plant encountered at that point; e.g. Bn = Betula nana.

Three maps of all 85 sampled plots in the Toolik Grid display (1) the topography of the top layer and bottom layer of the plant canopy, (2) the species at the top of the plant canopy, and (3) species at the bottom of the plant canopy. Fig. 4 shows the plots of 9 of the plots in the northwest corner of the grid. A similar set of maps was prepared for the plots in a grid at the nearby site of Imnavait Creek, which is on an older glacial surface.

The Toolik and Imnavait grids have been re-sampled at six-year intervals between 1989 and 2008. Preliminary results indicate that major changes to the structure and composition of the plant communities have occurred, with significant increases in the abundance of the dominant shrub, *Betula nana*, and decreases in the abundance of *Sphagnum* mosses (Figure 5). The long term monitoring has also revealed increases in the mean canopy height at both the Toolik and Imnavait grids. This may be due to a more dense canopy, a taller canopy, or a combination of these characteristics. Future analyses of the data set will examine the details of species occurrences with respect to ter-

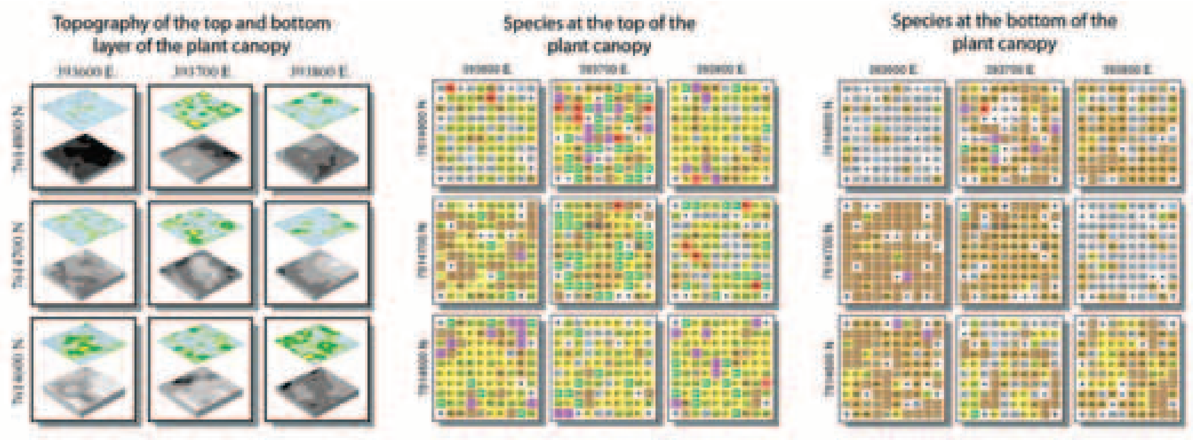

Figure 4: Detail showing structure and species composition in 9 sampled plots in the northwest corner of the Toolik Grid (of 85 total). The UTM coordinates of each plot are also shown.

rain variables in the GIS map database and the dynamics of vegetation changes.

The cause of the apparent tripling of canopy heights at both grids is not known. It could be due to more dense vegetation (for example, more leaves on the deciduous shrubs) or actual changes in height or a combination of both.

Future analyses of the data set will examine the details of species occurrences with respect to terrain variables in the GIS map database and the dynamics of vegetation changes.

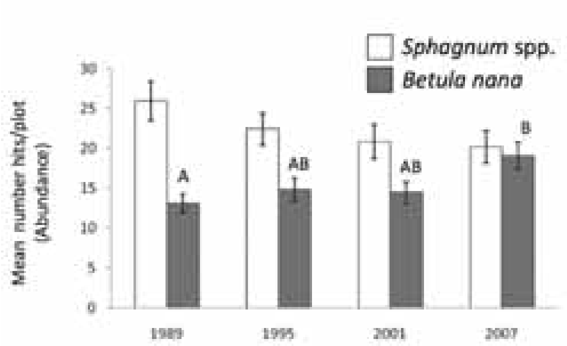

Figure 5: Changes in Betula nana and Sphagnum cover at Imnavait Creek (1989, 1995, 2001, 2007) Changes in the abundances of the deciduous shrub Betula nana and Sphagnum mosses from 1989 to 2007 at the Imnavait Creek Grid, AK. Letters indicate significant differences between years. Error bars are ± standard errors.

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CIRCUMPOLAR GEOBOTANICAL MAPPING: A WEB-BASED PLANT-TO-PLANET APPROACH FOR VEGETATION-CHANGE ANALYSIS IN THE ARCTIC

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Introduction

Vegetation maps of entire global biomes are needed for a wide variety of issues related to international development, climate change, and education. Maps that are made and accepted by the global vegetation-science community are required at several scales and should be accessible and easily used by students, scientists, land managers, and private industry in all countries. The worldwide web makes it possible to provide maps and digital data in a variety of formats, along with ancillary background and explanatory material.

A new «plant-to-planet» Toolik-Arctic Geobotanical Atlas (T-AGA) (http: //www.arcticatlas.org/) was designed to meet research and site management needs at the Toolik Field Station in northern Alaska. The ideas may prove useful for groups such as the Nordic countries that desire a more international approach that makes cross-border studies and applications easier. At the heart of the T-AGA is the desire to develop techniques for the worldwide vegetation-science community to map other entire biomes and eventually the whole Earth with a coordinated international approach.

The T-AGA hierarchy of maps

The atlas currently presents seven different scales of maps from the circumpolar Arctic down to 1 x 1-m plots (Figure 1). The T-AGA provides maps and information mainly for the Circumpolar Arctic, Arctic Alaska and the region around Toolik Lake, Alaska. The atlas is still in progress, but the intent is to eventually provide many more maps produced by the first author and many collaborators during 35-years of research in northern Alaska and circumpolar Arctic, including maps for the International Biological Programme Tundra Biome at Barrow (Walker 1977) the Prudhoe Bay Geobotanical Atlas (Walker et al. 1980), the Kuparuk River watershed (Muller et al. 1998), North Slope mapping (Muller et al. 1999), the Circumpolar Arctic Vegetation Map (CAVM) (CAVM Team et al. 2003), Arctic Alaska Tundra Map (Raynolds et al. 2006) and a hierarchy of maps developed for research at Imnavait Creek (Walker & Walker 1996) and Toolik Lake (Walker & Maier 2008).

There are four key aspects of the hierarchy of maps: (1) The «geobotanical mapping approach» provides information on a wide variety of variables important to vegetation at all scales. The geobotanical mapping methods were developed in the late 1970s at Prudhoe Bay, AK in recognition of the key role that landforms and parent material play in the spatial distribution of plant communities (Everett et al. 1978, Walker et al. 1980). The approach is similar in principal to a variety of other landscape-guided and integrated terrain-unit mapping approaches, whereby landforms are used to guide the delineation of map-polygon boundaries, and the map polygons are coded with a variety of independent geobotanical attributes (Zonneveld 1988, Dangermond & Harnden 1990). The GIS databases at most scales of the T-AGA hierarchy include domi-

Figure 1: Hierarchy of map areas in the T-AGA.

nant and subdominant vegetation, surface geomorphology, glacial geology, landforms, water cover, topography derived from digital elevation models, and NDVI. (2) The Braun-Blanquet approach is the standard for plant community nomenclature where ever possible. This system provides plant-community names that are widely accepted worldwide. (3) Detailed descriptions of all units are linked to field information from permanent plots with further links to important literature, photographs, and other supporting data, including photos and descriptions of all plant species mentioned in the atlas. (4) Standardized map legends and color systems make comparison and extrapolation between map scales and regions easier.

This paper focuses on maps developed for the circumpolar Arctic and the Toolik Lake area to illustrate how the map hierarchy (Figure 1) is being used to address questions related to a multi-scale analysis of Arctic climate change. This is part of the «Greening of the Arctic» project of the International Polar Year (http: //www.alaska.edu/ipy/news/AGU-Walker.xml, http: //classic.ipy.org/development/eoi/details.php?id=569#TOP),

Circumpolar and the Alaska Arctic vegetation maps

The CAVM is the result of an international 13-year effort that required considerable collaboration and compromise among the circumpolar countries to reach the final product (CAVM Team et al. 2003, Walker et al. 2005). The CAVM GIS database includes circumpolar maps of vegetation, bioclimate subzones, floristic subprovinces, substrate pH, landscape types, topography, wetlands, and plant biomass. The vegetation map was published at 1: 7.5 M scale (CAVM Team 2003) and the rationale, review of previous maps, methods, and analyses are presented in several papers (Walker 1995, Walker et al. 1995b, Walker 1999, Walker et al. 2002, Walker et al. 2005).

At the global scale the CAVM is proving to be a useful tool for a wide variety of scientific applications related to Arctic change analysis. Several recent papers have analyzed the spatial distribution of circumpolar vegetation and biomass with respect to variables in a circumpolar Arctic GIS database, including Arctic land temperatures permafrost distribution, lake cover, parent material pH, and glacial history (Raynolds et al. 2008, Raynolds & Walker 2008, Raynolds 2009, Raynolds & Walker 2009). The analysis found that land temperatures and glacial history are by far the most important variables affecting the fraction of photosynthetically active radiation recorded by satellite sensors and expressed as the Normalized Difference Vegetation Index (NDVI).

The 27-year record of NDVI derived from the NOAA AVHRR sensors (Tucker et al. 2005) is now being analyzed with respect to changing sea-ice and land-temperature conditions (Bhatt et al. 2008b, a, Bhatt et al. 2009a, Bhatt et al. 2009b). The study found that sea-ice concentrations in the 50-km coastal strips of 14 Arctic seas are strongly correlated with tundra summer land temperatures and NDVI of the tundra areas south of these strips. Another finding from this study shows that some of the largest percentage changes in NDVI are occurring in North America and in the coldest parts of the Arctic. A newly funded study will examine the atmospheric and oceanic circulation patterns that underlie the observed patterns of NDVI and land temperature change.

Another important derived set of products from the CAVM is a 1: 4-M scale vegetation map and GIS of Arctic Alaska (Raynolds et al. 2005, Raynolds et al. 2006). The vegetation map utilizes the underlying plant-community data of the CAVM to transform the 15 physiognomic vegetation units of the CAVM into 33 more detailed units. The map provides detailed information regarding the literature sources behind the vegetation units displayed on the map. A table on the back of the map presents the major plant communities that have been described in the literature for each combination of bioclimate subzone, floristic subprovince, parent material pH class, and mesotopographic position in Arctic Alaska (Raynolds et al. 2006).

Another map of the Kuparuk River watershed was used for extrapolating a wide variety of plot- and landscape-level research involving measurement of plant productivity, soil-carbon storage, trace-gas fluxes and active-layer depths to an entire large river watershed (Hobbie et al. 1998, Nelson et al. 1998, Ping et al. 1998, Reeburgh et al. 1998).

Regional-, landscape-, and plot-level maps of the Toolik Lake region

A new set of maps at three scales in the Toolik Lake region provides information for a variety of studies at this Arctic observatory (Walker and Maier 2008). At the regional level, the upper Kuparuk River basin

($850 km^2$), was mapped at 1: 25,000 scale (published at 1: 63,360 (1 inch = 1 mile, a standard mapping scale in the US). The resulting GIS database has been used for a wide variety of studies including a regional analysis of methane emission (Shippert 1997); extrapolation of biomass and NDVI measurements from plot studies to large regions (Shippert et al. 1995) and analysis of the role of glacial-surface age in biomass patterns (Walker et al. 1995a, Munger et al. 2008, Walker et al. 2009 submitted). Most recently repeat Landsat images have been used to examine where changes in plant production have been occurring most rapidly in the Toolik Lake region (Munger 2007). These studies indicate that changes between 1985 and 1999 were focused in areas of disturbance, especially along roads where dust and altered hydrology occur. Other areas of change occurred in the research areas at Toolik Lake, possibly due to the concentrated activities of field researchers, and on south-facing slopes with shrubby water tracks.

At the most detailed-level, a new set of maps depicts the baseline at 85 grid points of the 1.2 x 1.1-km Toolik Lake Grid. Permanent 1 x 1-m plots at each grid point were sampled in 1990 for monitoring changes to the vegetation (Walker et al. 2009, this volume). A similar dataset is in progress for the nearby Imnavait Creek grid. A methodology developed for the International Tundra Experiment (ITEX) permits near-exact repositioning of the frame for long-term monitoring (Walker 1996). Maps of each plot portray the height of the plant canopy, microrelief of the soil surface, and the species composition of the top and bottom layers of the plant canopy. The plots are monitored every 6 years using the same methods. Dr. Bill Gould and his students are currently monitoring the plots. Large changes occurred between 1990 and 2008. Average plant canopy height at each point increased by a factor of 3; shrub cover and graminoid cover increased, while moss cover decreased.

Conclusion

The Toolik-Arctic Geobotanical Atlas is still a work in progress. Eventually it will consolidate over 35 years of geobotanical mapping in northern Alaska and the circumpolar Arctic and will make the data available in an easily accessible format via the worldwide web. It has proven to be a useful tool in many studies including multi-scale analyses associated with the on-going «Greening of the Arctic» project and long-term monitoring of vegetation changes as part of the ITEX project. The approaches developed at Toolik Lake and the Arctic would be even more useful if extended to other Arctic observatories and to areas south of the Arctic tree line. A new initiative for mapping the circumboreal forests using similar methods is currently in the planning phase (http: //www.arcticportal.org/en/projects/cbvm) (Talbot 2008).

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MORE EFFICIENT VEGETATION MAPPING BY IMAGE ANALYSIS OF DIGITAL AERIAL PHOTOS

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Figure 1: Bedrock. Fieldwork in the study area in Blekinge in the south-eastern Sweden, 2008.

Abstract

The project «More efficient Vegetation Mapping by Digital Image Analysis of Aerial Photos» was carried out by Lantmäteriet in 2008. The objective of the project was to develop more time and cost efficient methods for vegetation mapping.

Today Lantmäteriet in Sweden use digital cameras for aerial photography. The digital aerial photos make it possible to use techniques until now applied for image analysis of satellite data.

A very promising method is based on segmentation of an ortho-photo-mosaic derived from the aerial photos. A non supervised classification of the segments is carried out and the result of the classification is manually labelled to vegetation classes.

One conclusion from the project was that the segment based classification was more efficient and to some extent also improved the quality of the delineation between forest and bedrock areas, compared to visual interpretation.

1 Introduction

Vegetation maps administrated by Lantmäteriet covers almost half of Sweden. The data is produced by visual interpretation of analogue colour infrared aerial photos. Since 2005 digital cameras are used for aerial photographing by Lantmäteriet in Sweden and the digital aerial photos opens for new applications and possibilities. Methods applied for satellite data can now, with some adjustments, be used for digital aerial photos. The purpose of this project, carried out by Lantmäteriet in 2008, was to develop more time and cost efficient methods for vegetation mapping still with high thematic quality.

2 Material and Methods

INPUT DATA
The digital aerial photographs used in the project are from the flying height of 4800 m. The geometric resolution is 2 m for the four multispectral bands (blue 400–580 nm, green 500–650 nm, red 590–675 nm, near infrared 675–850 nm) and 0,5 m for the pancromatic band (400–850 nm). The photos are orthocorrected and mosaiced together to bigger units.

STUDY AREA
The study area is located in Blekinge in the south-eastern part of Sweden, a coastal area with oak, beech, birch and other deciduous forests, pine forests, agricultural areas, pasture land and a lot of bedrock areas, with and without forest cover.

METHODS
Two different types of digital classifications were tested:

- Pixel-based classification
- Segmentation followed by a classification based on the segments

is then carried out. Finally the classes in the resulting classification are manually labelled to vegetation classes. The labelling is supported by field experience and visual stereo interpretation of the aerial photos.

To evaluate the method an independent visual interpretation of the same area was made. A comparison between the results from the visual interpretation and the segment-based classification was carried out. The landscape has a great deal of bedrock areas (Figure 1). In the visual interpretation the delineation between forest and open bedrock was very time-consuming. The comparison showed that the segment-based classification was more time effective and to some extent even

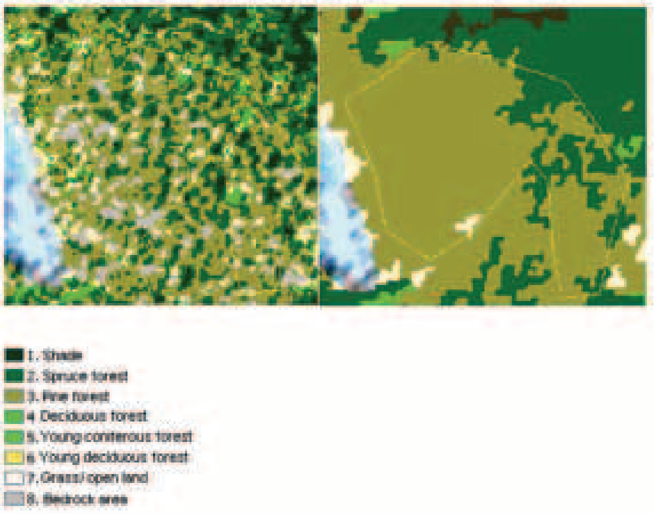

Figure 2: Example of known Pine forest area (yellow delimitation). Pixel-based (left) and a segment-based (right) classification.

3 Results

A pixel-based classification is very detailed and as maps are generalised products, this is usually a disadvantage for vegetation mapping.

The other method tested in the project, is a digital classification based on segments. Segmentation is an automatic, digital process where the image is divided into areas with similar characteristics regarding colour, texture etc. An unsupervised classification, based on the statistics of the segments (mean value / band)

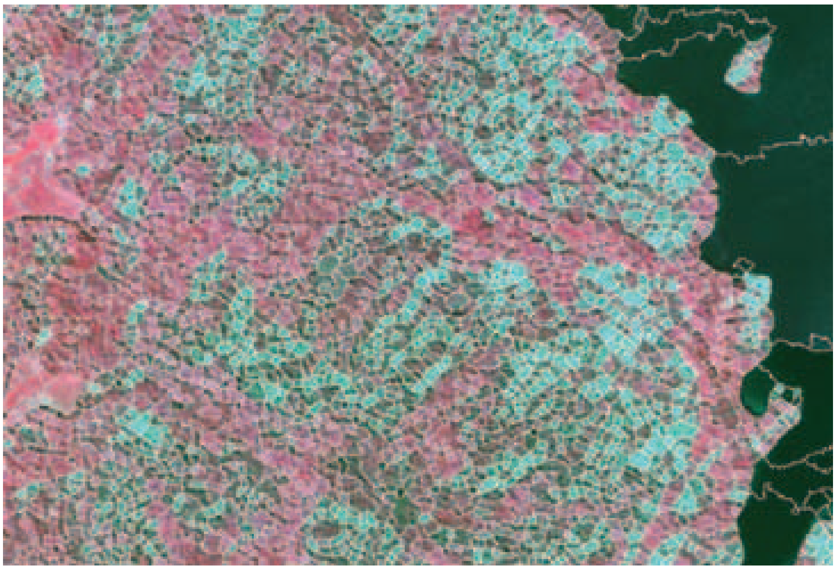

Figure 3: Aerial Infrared image divided into segments.

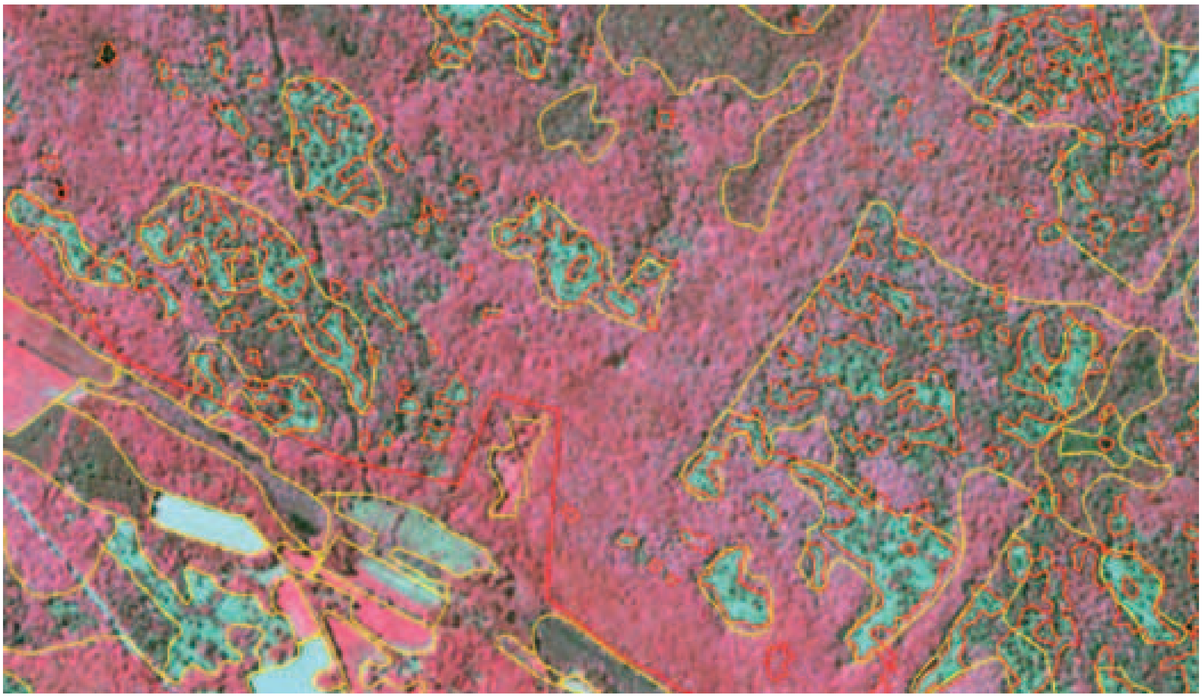

Figure 4: Delimitations from visual interpretation in yellow and from segment-based classification in red.

improved the quality of the delineation of the open bedrock areas (Figure 3).

One advantage of the segment-based classification (compared to a pixel-based) is that the result is generalized and the generalization is based on the information in the image. The result is more like the result from visual interpretation, which is important if you want to vary between digital and manual methods. Another advantage of segment-based classification is that other characteristics than spectral, for example texture can be used.

4 Discussion

Conclusions from the project are that classification based on segments makes it possible to produce vegetation maps more efficient and could to some extent even improve the quality. Preserving high thematic quality when integrating automatic methods demand that the production is divided into steps where different methods, including visual interpretation, can be used for different classes. The methods should also be adjusted to different regions due to the variations in nature.

Digital methods should preferable be developed and used for common classes and the most time-consuming steps.

Good geometric quality of existing map data used in the production is important for both the quality and the efficiency. The size of the orthophoto-mosaics, used for segmentation and classification, is also important for the efficiency of the production. The segmentation softwares used in the project had limitations in image size.

ASSESSMENTS OF LOSSES OF OLD GROWTH FOREST

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Abstract

By making a temporal interpretation study of infra red coloured (CIR) aerial photos it is possible to evaluate losses of old growth forest in a limited area of the landscape. The study consists of six landscape areas with coniferous forest and the period was between (approximately) 1980 and 2003. The first step was to identify old growth forest and separate it from managed forest. The second step was to identify clear cut areas inside the polygons of old growth. The rate of losses is high in the beginning of the study and slows down in the end except for two of the areas. Finally, there is a discussion about the results and some conclusions about the method.

1 A short forest history description as a background

The Swedish woods in the northern part of the country have been influenced by forestry for more than 200 years. In the preindustrial time the economical purpose with forestry was production of tar and potash and later to supply the mining industry with fuel. But the large scale transformation of the northern Swedish old growth forests to managed forests started around 1830 in the western part of the country (province of Värmland) the so called timber frontline. In 1870–1880 the timber frontline had reached Lapland in the northern most part of Sweden. At that time timber from Scandinavia was well paid by different industry branches in England and much of the solid wood products were exported. Because of that, the old growth forests have continuously decreased decade after decade and after the world war two, we can add the pulp industry as a big consumer of forest products. Now just small spots of old growth only remains along the mountain range and at some places in the northern most part of the country.

As the old forest is very important for the biological diversity, the decreasing areas of old growth caused severe concerns among the authorities of nature conservation and NGO: s. In the beginning of 1990 a new forestry act was implemented and one the major lines in the new law is equality between the environmental and production objectives.

A couple of years after the forestry act was implemented it was time to evaluate the environmental effects of the new legislation. The Swedish environmental protection agency which has one of its main tasks to monitor the state of the environment in Sweden like air, waters, wetlands, forests etc, was responsible for this project of evaluation. One part of it was to find a method that could give some basic data about losses of old growth forest. One way to measure these changes is to make a temporal study of CIR aerial photos and pancromatic photos.

2 Material and methods

2.1 Selection of study sites

The study started by Lars Anderson at the Swedish mapping, cadastral and land registration authority in 1997 with four landscape areas. 2003 the Swedish environmental protection agency wanted to upgrade the study and added two more areas in the province of Norrbotten. I made the second part of the study. With help of experience and knowledge of the regional administrative board of nature conservation the areas that most probably contains the old natural forest according to the project definition were selected. Planned and decided nature reserves must not be dominant. We avoided areas with a high proportion of cultural landscapes, marshes, lakes and streams. Selected areas are in the inland, non-coastal or mountain regions. The six landscape areas have approximately the same size around 5000 hectares.

Figure 1: The six landscape areas.

2.2 Photo interpretation

I started to identify old growth forest in the CIR aerial photos in an analytic stereo instrument planicomp P 33. The next step was to identify cuttings inside the polygons of the old growth in pancromatic photos. To get the latest information about the cuttings I had to use satellite detection while there were no aerial photos available from 2003.

To be able to make the temporal comparison between different years of losses of old growth forest I had to categorize the years of aerial photo registration in five groups.

2.3 Fieldwork and GIS analysis

We visited every landscape area in field with purpose to validate if the interpreted areas of old growth forest also met the definitions of old growth and to calibrate how it looks like in the CIR photo.

The last step was to make a GIS analysis, primary to make the topological controls and area calculations.

2.4 The applied definitions of cutting operations were.

- Fewer than 100 trees per hectare spread over the whole cutting area in purpose for stand of seed trees, shelterwood, nature conservation purposes
- Other operations like thinning or with denser shelterwood with more than 100 trees, the area were considered as not cut, but a note was made

2.5 The applied definitions of old growth forest were.

- Forest at age more than 160 *(Of course not visible in CIR photos but indirect parameters like crown size and tree height can be used to estimate age)*
- Multi layered structure with trees in multiple age and size
- A significant amount of dead wood like snags, logs and standing dead trees
- During fieldwork, recorded the presence of red listed species that demands long continuity of trees and logs

3 Results

The proportion of old growth forest has decreased more or less in all landscape areas throughout all occasions.

Table 1: Years of CIR photos and *satellite scenes.

Landscape areas	Occasion no 1	Occasion no 2	Occasion no 3	Occasion no 4	Occasion no 5*
Alken-Örvattnet	1980	1988	1994	1997	2004
Mangslid	1980	1988	1995	1997	2003
Övsjön	1983	1989	1994	1997	2003
Storholmsjö-Föllinge	1980	1989	1994	1997	2004
Arvidsjaur-Lehatt	1981	1988	1994	no photos	2003
Övertorneå-Ahmajärvi	1979	1987	1991	1997	2003

Table 2: The proportion of remaining old growth forest from occasion 1 to occasion 5.

Landscape areas	Occasion no 1	Occasion no 2	Occasion no 3	Occasion no 4	Occasion no 5*
Alken-Örvattnet	3,3 %	2,8 %	2,5 %	2,5 %	2,5 %
Mangslid	10,6 %	5,4 %	4,7 %	4,0 %	3,9 %
Övsjön	1,9 %	1,7 %	1,6 %	1,6 %	1,3 %
Storholmsjö-Föllinge	47,2 %	42,8 %	40,3 %	40,3 %	38,7 %
Arvidsjaur-Lehatt	55,0 %	46,2 %	39,1 %	no data	37,3 %
Övertorneå-Ahmajärvi	19,4 %	18,7 %	18,0 %	14,1 %	12,9 %

The rate of losses of old growth is in general quite high in the beginning of the study but it slows down in the end.

Table 3: The deforestation rate of old growth forest at six landscape area at four different time interval.

Landscape areas	1– 2	2– 3	3– 4	4– 5
Alken-Örvattnet	14,9 %	10,3 %	2,0 %	5,5 %
Mangslid	48,7 %	14,2 %	13,5 %	3,0 %
Övsjön	11,5 %	4,3 %	3,0 %	17,2 %
Storholmsjö-Föllinge	9,1 %	6,0 %	0,0 %	3,9 %
Arvidsjaur-Lehatt	16,0 %	15,6 %	no data	4,4 %
Övertorneå-Ahmajärvi	3,5	3,6 %	21,7 %	8,6 %

5 Discussion

5.1 Why does it looks like this?

The areas in Alken-Örvattnet and Övsjön are situated in regions with a quite long history of large scale forestry and very little remains of old growth forest already in occasion 1. That can explain why the rate of losses is low and slows down already in interval 2– 3. In other words there are not so much left of old growth and they are probably situated at steep slopes, wet habitats or other sites where it is difficult of access. Cuttings of the last old growth forests in these areas, probably is quite expensive and will not give any good profit.

While there are not so much of left of old growth forest already in the beginning of the study, just a few hectares of cuttings can increase the rate and that can explain why the rate suddenly increases in occasion 5 at Övsjö.

Mangslid has a rather high deforestation rate of old growth forest at occasion 1 and has also a quite long history of large scale forestry which continues to the end of 1980. After that, very little remains of old growth in that area.

Arvidsjaur-Lehatt and Storholmsjö-Föllinge have a relatively high proportion of old growth forest at all five occasions compare to the others. There must be many explanations to this but one reason is probably that the large scale forestry started later here than in the other landscape areas. The forests show two faces in this area one with old growth and the other is clear-cut areas.

In general, the explanation why the rate decreases in all areas in the end of the study period can be the debate about forestry versus nature conservation that started in the late nineteen eighties. The forestry companies and the Swedish environmental protection agency were under pressure to save the last areas of old growth forests at that time.

An exception is Övertorneå-Ahmajärvi where the losses of old growth have increased to 21 % between occasion 3 and 4. I have no good explanation why this happened.

5.2 Advantages and disadvantages with the method

- – Registration year for the CIR photos and pancromatic photos is critical
- – Time consuming. It is not a one day job to cover vast areas
- -+ The accuracy of the interpretations. Not all old growth polygons are correct by definition but in general it is easier to identify old growth forests in CIR photos in the northern parts than in the southern parts of the country.

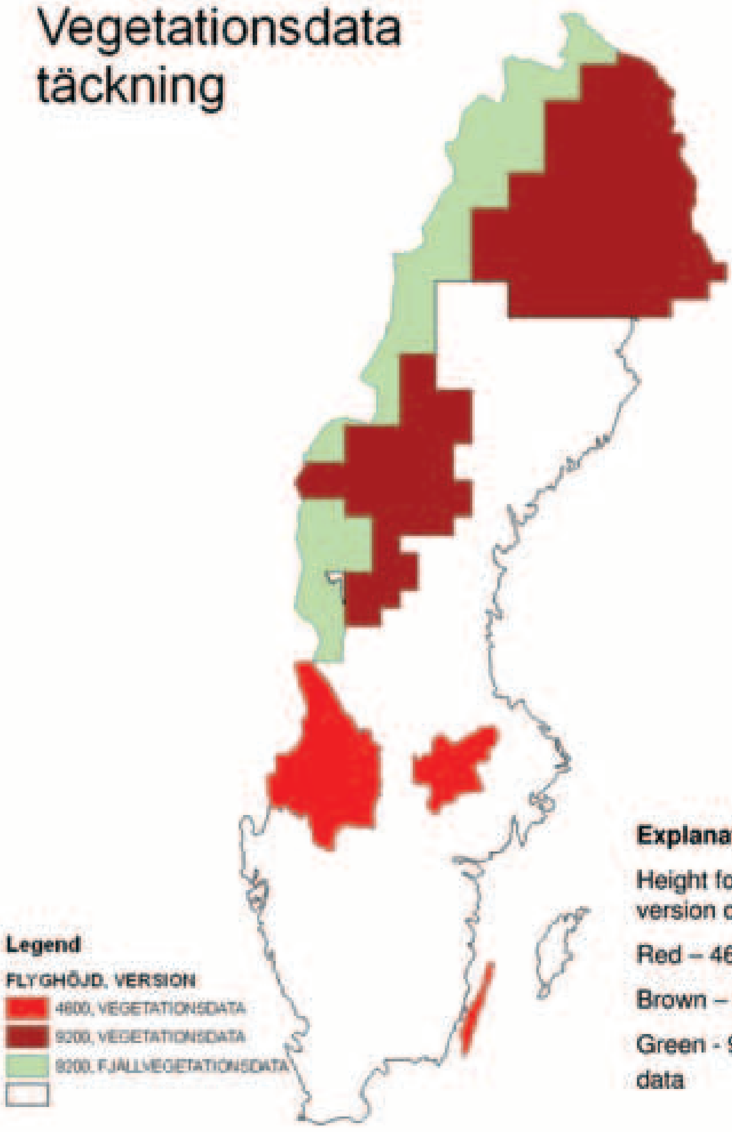
- + Verifying the existence of old growth forest in the past. It is always good to have the right information about the historical landscape.
- + Relating the changes in the old growth extent to political decisions. Like a new legislation as the new forestry act, new environmental laws, changes in tax rules, implementation of eco label forestry or other occurrences in the society that can influence the logging rate of old growth. By using CIR photos it is possible to get an overview of what is going on.

Acknowledgements

I would like to thank my colleague Lars Anderson who introduced me in his part and helped me to complete the study.

Vegetation maps, classification and symbols of Lantmäteriet, Sweden.

Lars Andersson, Lantmäteriet,
the Swedish mapping, cadastral and land registration authority.



Explanation of legend:

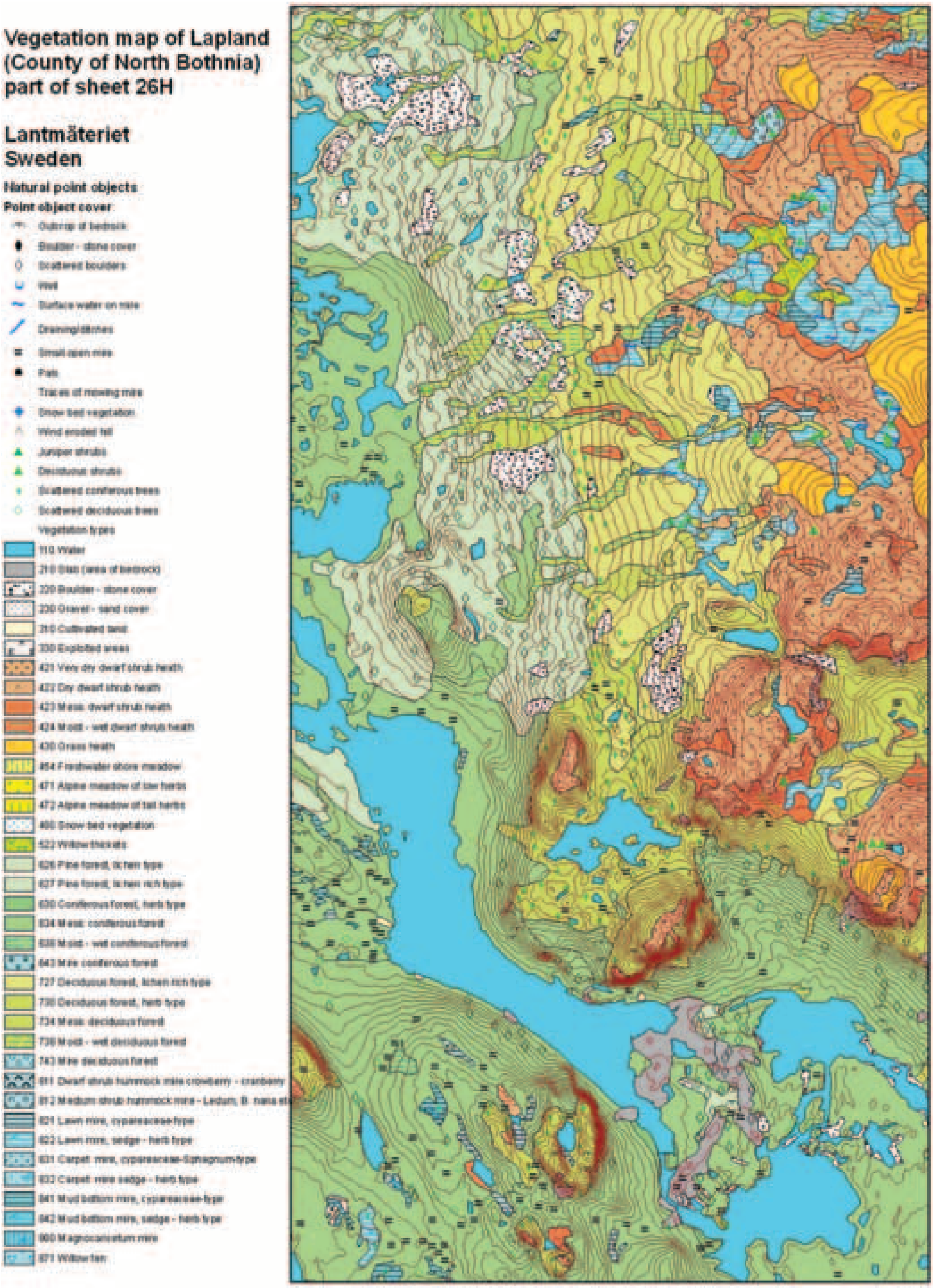
Height for taking aerial photo, version of data

Red – 4600 m, vegetation data

Brown – 9200 m, vegetation data

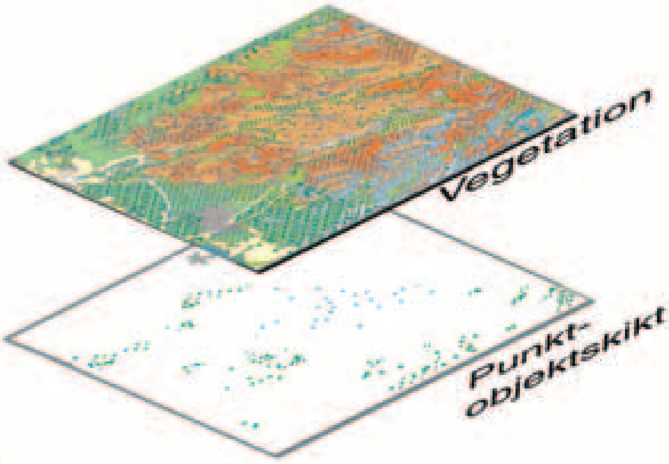
Green - 9200 m, alpine vegetation data

Mapped areas 2009 - vegetation data of Lantmäteriet.


Vegetation map of Lapland (County of North Bothnia) part of sheet 26H
Lantmäteriet
Sweden
Natural point objects
Point object cover
Outcrop of bedrock
Boulder - stone cover
Scattered boulders
Well
Surface water on mire
Drainingditches
Small open mire
Pals
Traces of mowing mire
Snow bed vegetation
Wind eroded fell
Juniper shrubs
Deciduous shrubs
Scattered coniferous trees
Scattered deciduous trees
Vegetation types
110 Water
210 Slab (area of bedrock)
220 Boulder - stone cover
230 Gravel - sand cover
310 Cultivated land
330 Exploited areas
421 Very dry dwarf shrub heath
422 Dry dwarf shrub heath
423 Mesic dwarf shrub heath
424 Moist - wet dwarf shrub heath
430 Grass heath
454 Freshwater shore meadow
471 Alpine meadow of low herbs
472 Alpine meadow of tall herbs
480 Snow bed vegetation
522 Willow thickets
626 Pine forest, lichen type
627 Pine forest, lichen rich type
630 Coniferous forest, herb type
634 Mesic coniferous forest
638 Moist - wet coniferous forest
643 Mire coniferous forest
727 Deciduous forest, lichen rich type
730 Deciduous forest, herb type
734 Mesic deciduous forest
738 Moist - wet deciduous forest
743 Mire deciduous forest
811 Dwarf shrub hummock mire crowberry - cranberry
812 Medium shrub hummock mire - Ledum, B. nana etc
821 Lawn mire, cyparaceae-type
822 Lawn mire, sedge - herb type
831 Carpet mire, cyparaceae-Sphagnum-type
832 Carpet mire sedge - herb type
841 Mud bottom mire, cyparaceae-type
842 Mud bottom mire, sedge - herb type
860 Magnocaricetum mire
871 Willow fen

Vegetation data structure of Lantmäteriet

- Data consists of 2 (in this example) to 4 separate covers/layers or shapefiles
- Vegetation areas (c. 70 types, > 300 varieties due to supplementary info on wetland vegetation, tree and shrub layer)
- forest age class areas (0 – 5 classes)
- natural line objects (0 - 7 classes)
- natural point objects (20 – 30 classes)
- Detail level of vegetation area ranges from 9 hectares in alpine maps to 0,25 hectares in lowland maps, applied technique allows more detailed mapping
- Based on interpretation of CIR aerial photos with supporting field work



Direktoratet for **naturforvaltning**

Fact sheet

Mapping and use of biodiversity data

Knowledge about biological diversity must be readily available for land-use planners, developers and everyone else. Easily understandable regulations are essential if we are to safeguard natural assets.

Kartlegging av biologisk mangfold

Game mapping

- Game concerns birds, mammals, reptiles and amphibians
- Game are mapped in accordance with DN Manual 11 on game mapping
- Mapping has taken place for several decades
- 53 000 localities are stored in the 'Naturbase' database

Habitat mapping on land

- Specially valuable habitats are mapped using methods presented in DN Manual 13 on mapping habitats on land (including fresh water)
- Mapping started in 1999
- 32 000 localities are stored in the 'Naturbase' database

Marine mapping

- Marine mapping concerns habitats and occurrences of species, and is described in DN Manual 19 on marine mapping
- Mapping started in 2008
- 8000 localities are stored in the 'Naturbase' database

Red-listed species (excluding game)

- Specimens of species that are discovered are stored in university museum collections
- The web portal, 'Artskart', contains accessible information on the occurrence of species
- Everyone may feed their observations into the 'Artsobservasjoner' database

Occurrences in fresh water

- Valuable occurrences in fresh water are mapped in accordance with DN Manual 15
- The data is fed into the 'Vannmiljøbasen' database.
- Freshwater habitats are mapped in accordance with DN Manual 13 and fed into the 'Naturbase'.

The Directorate for Nature Management (DN) is the central, executive and advisory management body concerned with preserving biodiversity, outdoor recreation and the use of natural resources. DN's vision, For Life in Nature and Nature in Life, is an expression of this. DN is an agency under the Ministry of the Environment. Authority to manage natural resources is given through various Acts and Regulations. In addition to statutory tasks, the Directorate is responsible for identifying, preventing and solving environmental problems through cooperation and providing advice and information to other authorities and the general public.

Directorate for Nature Management, NO-7485 Trondheim, Norway. Telephone: +47 73 58 05 00 www.dirnat.no

Important premises for using the data

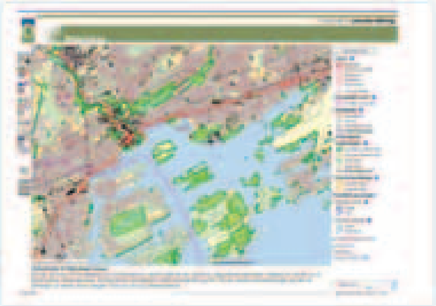
The data must have good quality and coverage

Several Ministries cooperate on a programme to map and monitor biodiversity. The methodology presented in DN Manuals makes demands on quality, which must be met before the data can be fed into the 'Naturbase'.

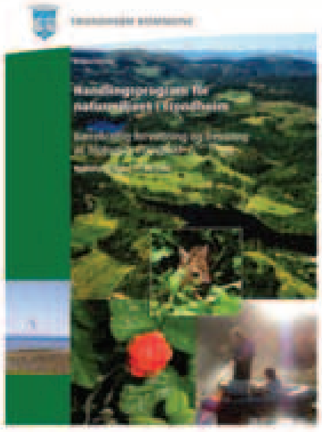
Availability for users

- **Naturbase'** gives an overview of habitat localities and areas inhabited by game
- The **'Artskart'** web portal gives an overview of the occurrences of species recorded in the principal databases (such as those at the university museums).
  Data in '**Artsobservasjoner**' (Species observations) are also available on **'Artskart'** (Species maps)

For local authorities, it is important that data from the 'Naturbase' and 'Artskart' databases can be integrated with their own computer programs. They can now download 'Naturbase' directly into these using WMS services. In spring 2011, the 'Naturbase' will become net-based so that data can be directly integrated with municipal computer programs. This will also simplify the updating of the data.



Habitat localities in Sandvika, near Oslo, illustrated through the Access tool in the Naturbase program



Use of data in decision-making processes

We need clearly understandable regulations if we are to limit the loss of biological diversity.

• The **Planning and Building Act** states that plans must describe expected consequences for biological diversity. Regional plans, municipal plans and development plans which may have significant impacts on the environment and society must be subjected to specially detailed investigations. The recently enacted Planning and Building Act has introduced *concern zones* to clarify where it is particularly important to pay consideration in land-use plans.

• The **Nature Diversity Act** provides special protection to selected habitats and endangered species.

Facts

- A precondition for feeding data on habitats and game into the 'Naturbase' database is that the criteria laid down in DN Manuals are adhered to
- The general public has access to data contained in the 'Naturbase' and 'Artskart' databases (excluding sensitive data).
- The Planning and Building Act and the Nature Diversity Act are intended to safeguard natural assets

Resources

- Directorate for Nature Management: www.dirnat.no
- Naturbase: www.naturbase.no
- Norwegian Biodiversity Information Centre: www.artsdatabanken.no
- Species observations: www.artsobservasjoner.no
- Distribution maps of species: www.artskart.artsdatabanken.no

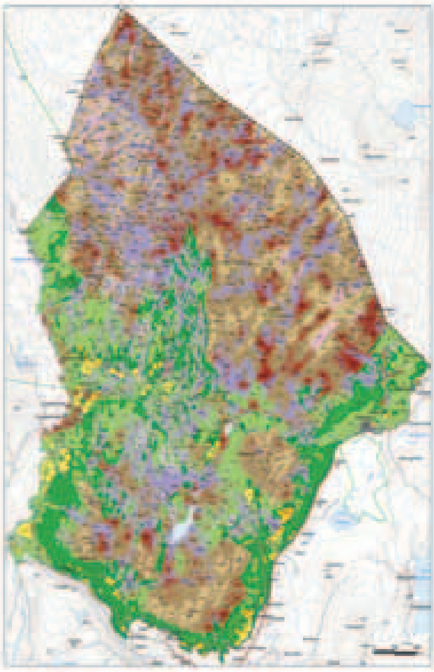
VEGETATION MAP

- as close as possible to the nature...

Vegetation maps provides a simplified image of the mosaic of vegetation types which constitute the natural plant cover. A vegetation type is a caracteristic collection of plant species which will be found on places with similar growth conditions. If we exploit the knowledge that the plant cover provides us regarding growth conditions, the vegetation map is the type of map which will give us the most versatile information regarding natural resources. This is the closest approach to an ecologic mapping. The vegetation map provides us with information about the natural resources and its distribution in the landscape. With in-depth knowledge of the classes and their contents, management schemes can be implemented for farmers, environmental authorities and other users.

In Norway today, two types of nation wide mapping systems exist. One for detailed mapping in 1: 5 000-20 000, the second for survey mapping in 1:25 000-50 000.
Entities from the detailed system can be combined to entities in the survey system.

Much of the effort behind a vegetation map relies on the field work. The mapping takes place as a combination of visual interpretation in the field and interpreting aerial photos. From changes in colour and structure in the image and ecological knowledge. A magnifying stereoscope is used in order to get a three dimensional image of the landscape. In the field, the vegetation gets classified into types, and borders are drawn around those. In the survey mapping, the interpreter will handle approximately 3 km^2 wood and 5 km^2 mountain daily. In detailed mapping just 0,5-1 km^2 daily. The least figure area is ten decars, but this can be lower on more important areas.



Thematic maps: Information provided by the vegetation maps can be hard to grasp without proper botanical and ecological knowledge. Processing of data in a geographic information system gives possibilities to sort different properties which can be tied to the vegetation types. This can then be presented as derived themes for different users need, presented as thematic maps or area statistics.

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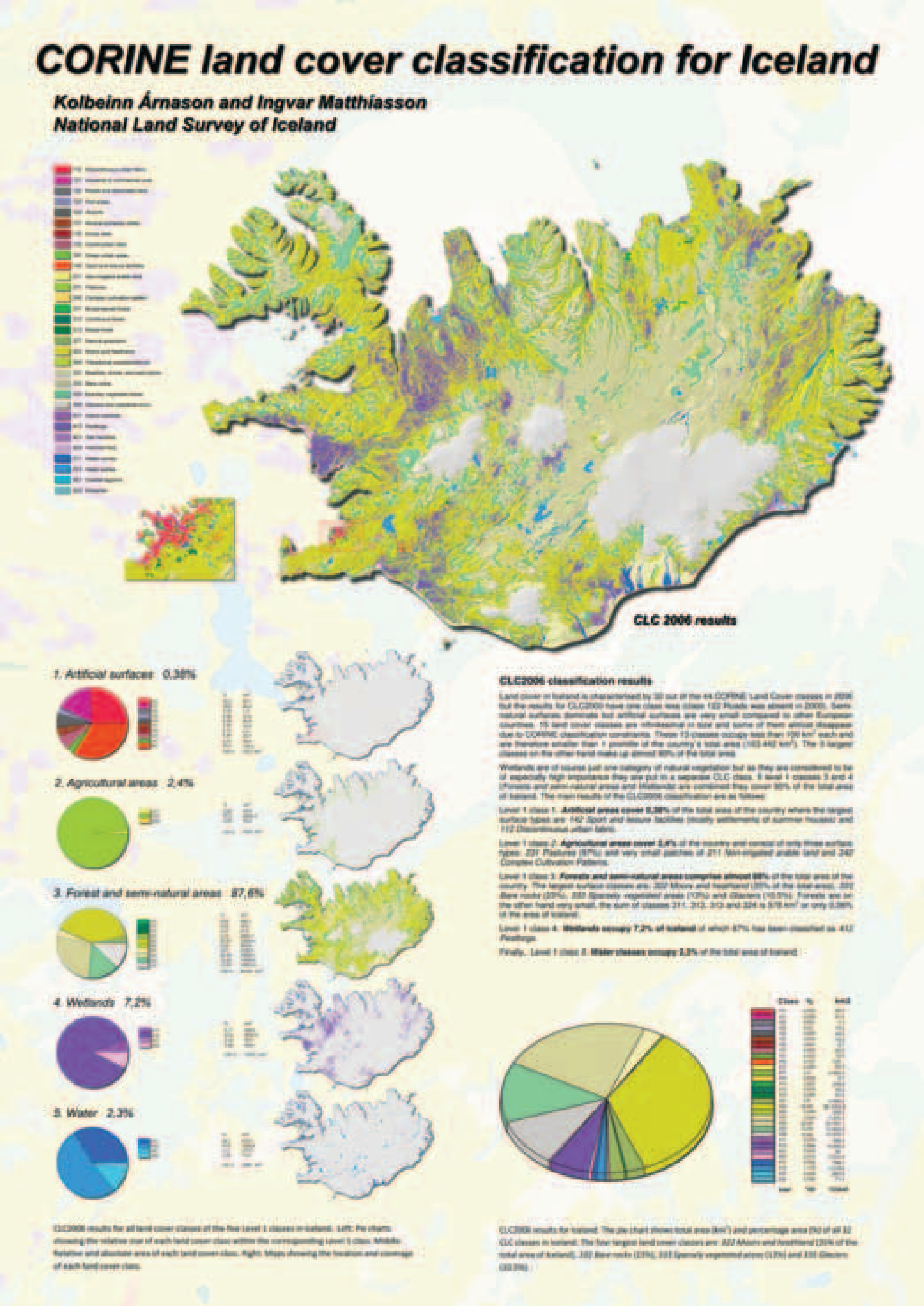
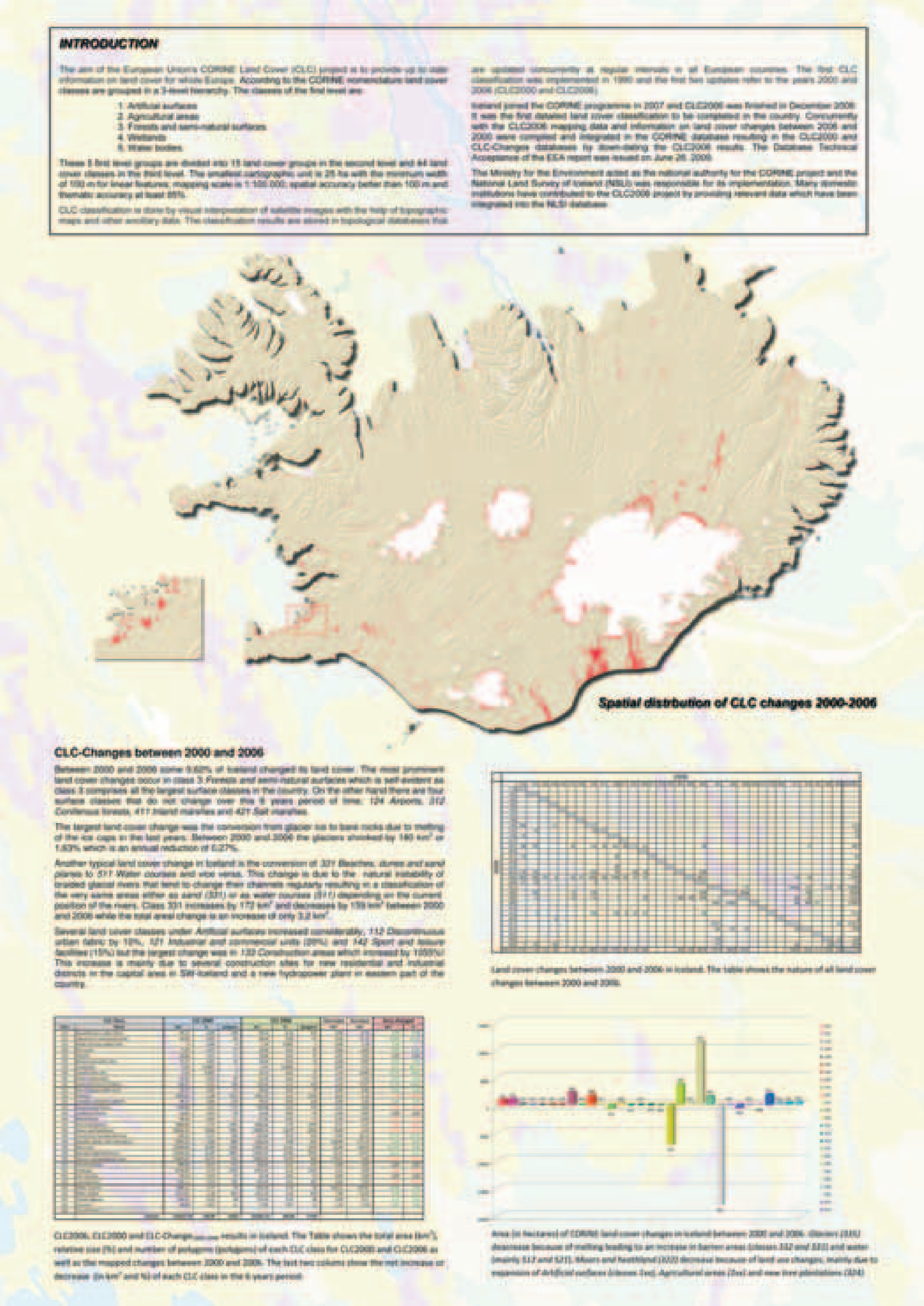


CORINE land cover classification for Iceland

Kolbeinn Árnason and Ingvar Matthiasson
National Land Survey of Iceland

CLC2006 classification results

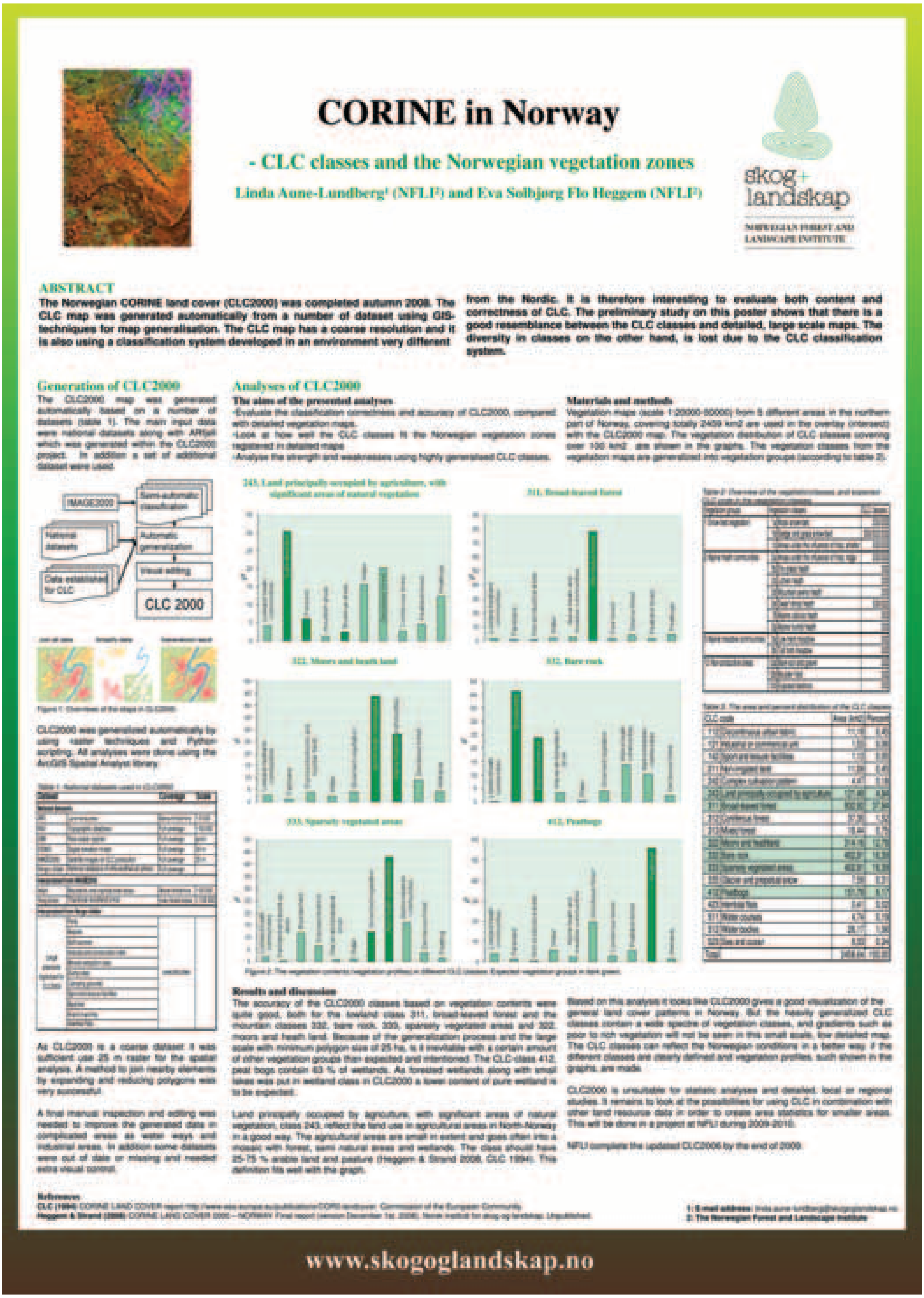


INTRODUCTION

1. Artificial surfaces
2. Agricultural areas
3. Forests and semi-natural surfaces
4. Wetlands
5. Water bodies

Spatial distribution of CLC changes 2000-2006

CLC-Changes between 2000 and 2006



CORINE in Norway

- CLC classes and the Norwegian vegetation zones

Linda Aune-Lundberg[1] (NFLI[2]) and Eva Solbjørg Flo Heggem (NFLI[2])

ABSTRACT

The Norwegian CORINE land cover (CLC2000) was completed autumn 2008. The CLC map was generated automatically from a number of dataset using GIS-techniques for map generalisation. The CLC map has a coarse resolution and it is also using a classification system developed in an environment very different from the Nordic. It is therefore interesting to evaluate both content and correctness of CLC. The preliminary study on this poster shows that there is a good resemblance between the CLC classes and detailed, large scale maps. The diversity in classes on the other hand, is lost due to the CLC classification system.

Generation of CLC2000

The CLC2000 map was generated automatically based on a number of datasets (table 1). The main input data were national datasets along with AR[illegible] which was generated within the CLC2000 project. In addition a set of additional dataset were used.

Figure 1: Overview of the steps in CLC2000.

CLC2000 was generalized automatically by using raster techniques and Python-scripting. All analyses were done using the ArcGIS Spatial Analyst library.

Table 1: National datasets used in CLC2000

As CLC2000 is a coarse dataset it was sufficient use 25 m raster for the spatial analysis. A method to join nearby elements by expanding and reducing polygons was very successful.

A final manual inspection and editing was needed to improve the generated data in complicated areas as water ways and industrial areas. In addition some datasets were out of date or missing and needed extra visual control.

Analyses of CLC2000

The aims of the presented analyses

- Evaluate the classification correctness and accuracy of CLC2000, compared with detailed vegetation maps.
- Look at how well the CLC classes fit the Norwegian vegetation zones registered in detailed maps.
- Analyse the strength and weaknesses using highly generalised CLC classes.

Materials and methods

Vegetation maps (scale 1:20000-50000) from 5 different areas in the northern part of Norway, covering totally 2409 km2 are used in the overlay (intersect) with the CLC2000 map. The vegetation distribution of CLC classes covering over 100 km2 are shown in the graphs. The vegetation classes from the vegetation maps are generalized into vegetation groups (according to table 2).

Figure 2: The vegetation contents (vegetation profiles) in different CLC classes. Expected vegetation groups in dark green.

Table 2: Overview of the vegetation classes and expected CLC-code in the vegetation groups

Table 3: The area and percent distribution of the CLC classes

Results and discussion

The accuracy of the CLC2000 classes based on vegetation contents were quite good, both for the lowland class 311, broad-leaved forest and the mountain classes 332, bare rock, 333, sparsely vegetated areas and 322, moors and heath land. Because of the generalisation process and the large scale with minimum polygon size of 25 ha, is it inevitable with a certain amount of other vegetation groups than expected and intentioned. The CLC-class 412, peat bogs contain 63 % of wetlands. As forested wetlands along with small lakes was put in wetland class in CLC2000 a lower content of pure wetland is to be expected.

Land principally occupied by agriculture, with significant areas of natural vegetation, class 243, reflect the land use in agricultural areas in North-Norway in a good way. The agricultural areas are small in extent and goes often into a mosaic with forest, semi natural areas and wetlands. The class should have 25-75 % arable land and pasture (Heggem & Strand 2008, CLC 1994). This definition fits well with the graph.

Based on this analysis it looks like CLC2000 gives a good visualization of the general land cover patterns in Norway. But the heavily generalized CLC classes contain a wide spectre of vegetation classes, and gradients such as poor to rich vegetation will not be seen in this small scale, low detailed map. The CLC classes can reflect the Norwegian conditions in a better way, if the different classes are clearly defined and vegetation profiles, such shown in the graphs, are made.

CLC2000 is unsuitable for statistic analyses and detailed, local or regional studies. It remains to look at the possibilities for using CLC in combination with other land resource data in order to create area statistics for smaller areas. This will be done in a project at NFLI during 2009-2010.

NFLI complete the updated CLC2006 by the end of 2009.

References:
CLC (1994): CORINE LAND COVER report http://www.eea.europa.eu/publications/COR0-landcover. Commission of the European Community.
Heggem & Strand (2008): CORINE LAND COVER 2000 – NORWAY. Final report (version December 1st, 2008). Norsk institutt for skog og landskap. Unpublished.

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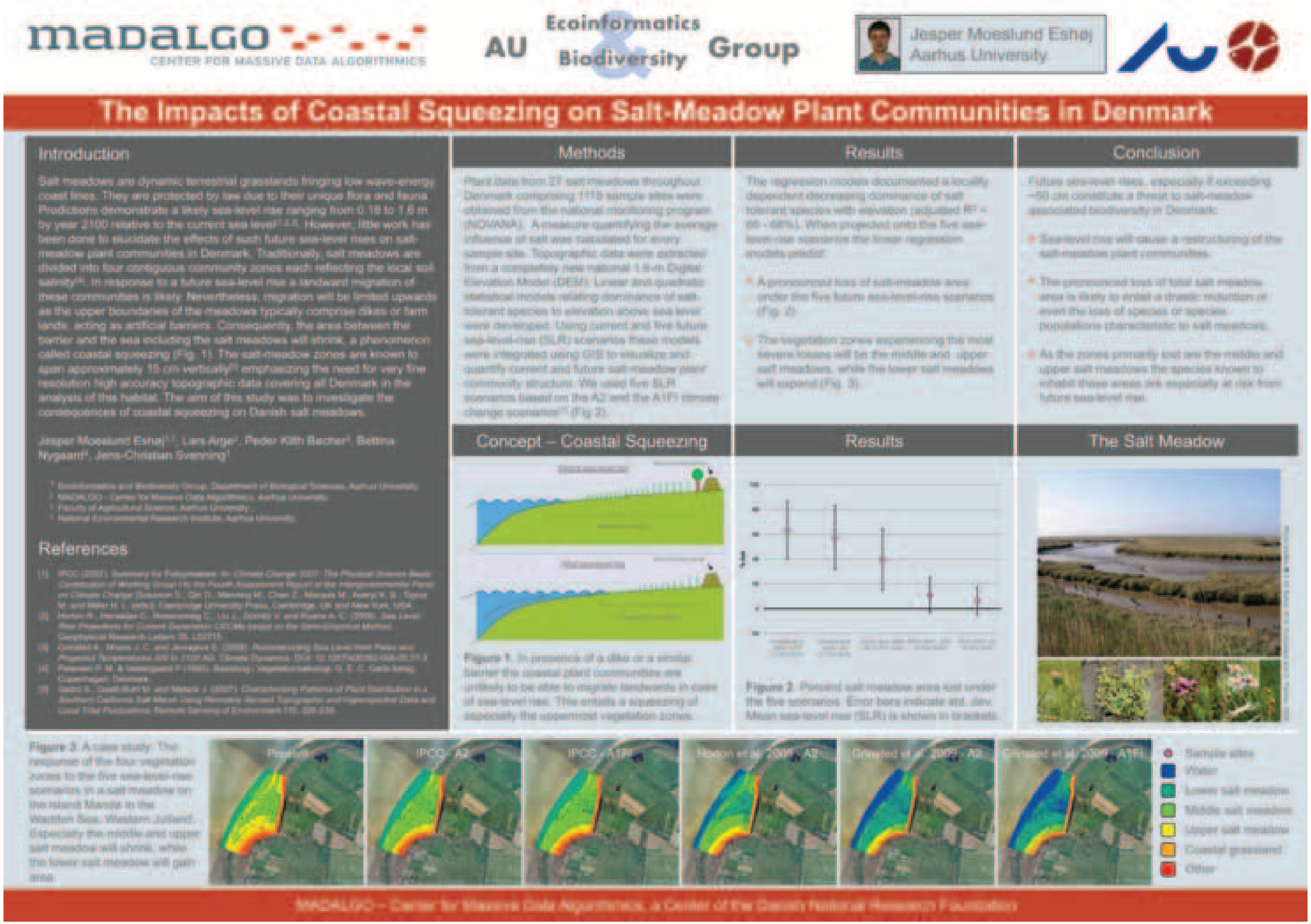

Jesper Moeslund Eshøj
Aarhus University

The Impacts of Coastal Squeezing on Salt-Meadow Plant Communities in Denmark

Introduction

Salt meadows are dynamic terrestrial grasslands fringing low wave-energy coast lines. They are protected by law due to their unique flora and fauna. Predictions demonstrate a likely sea-level rise ranging from 0.18 to 1.6 m by year 2100 relative to the current sea level[1,2,3]. However, little work has been done to elucidate the effects of such future sea-level rises on salt-meadow plant communities in Denmark. Traditionally, salt meadows are divided into four contiguous community zones each reflecting the local soil salinity[4]. In response to a future sea-level rise a landward migration of these communities is likely. Nevertheless, migration will be limited upwards as the upper boundaries of the meadows typically comprise dikes or farm lands, acting as artificial barriers. Consequently, the area between the barrier and the sea including the salt meadows will shrink, a phenomenon called coastal squeezing (Fig. 1). The salt-meadow zones are known to span approximately 15 cm vertically[5] emphasizing the need for very fine resolution high accuracy topographic data covering all Denmark in the analysis of this habitat. The aim of this study was to investigate the consequences of coastal squeezing on Danish salt meadows.

Jesper Moeslund Eshøj[1,2], Lars Arge[2], Peder Klith Bøcher[3], Bettina Nygaard[4], Jens-Christian Svenning[1]

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[2] MADALGO - Center for Massive Data Algorithmics, Aarhus University
[3] Faculty of Agricultural Sciences, Aarhus University
[4] National Environmental Research Institute, Aarhus University

References

[1] IPCC (2007). Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S., Qin D., Manning M., Chen Z., Marquis M., Averyt K. B., Tignor M. and Miller H. L. (eds)]. Cambridge University Press, Cambridge, UK and New York, USA.
[2] Horton R., Herweijer C., Rosenzweig C., Liu J., Gornitz V. and Ruane A. C. (2008). Sea Level Rise Projections for Current Generation CGCMs based on the Semi-Empirical Method. Geophysical Research Letters 35, L02715.
[3] Grinsted A., Moore J. C. and Jevrejeva S. (2009). Reconstructing Sea Level from Paleo and Projected Temperatures 200 to 2100 AD. Climate Dynamics. DOI: 10.1007/s00382-008-0507-2
[4] Petersen P. M. & Vestergaard P. (2006). Basisbog i vegetationsøkologi. G. E. C. Gads forlag, Copenhagen, Denmark.
[5] Sadro S., Gastil-Buhl M. and Melack J. (2007). Characterizing Patterns of Plant Distribution in a Southern California Salt Marsh Using Remotely Sensed Topographic and Hyperspectral Data and Local Tidal Fluctuations. Remote Sensing of Environment 110, 226-239.

Methods

Plant data from 27 salt meadows throughout Denmark comprising 1115 sample sites were obtained from the national monitoring program (NOVANA). A measure quantifying the average influence of salt was calculated for every sample site. Topographic data were extracted from a completely new national 1.6-m Digital Elevation Model (DEM). Linear and quadratic statistical models relating dominance of salt-tolerant species to elevation above sea level were developed. Using current and five future sea-level-rise (SLR) scenarios these models were integrated using GIS to visualize and quantify current and future salt-meadow plant community structure. We used five SLR scenarios based on the A2 and the A1FI climate change scenarios[1] (Fig 3).

Concept – Coastal Squeezing

Figure 1. In presence of a dike or a similar barrier the coastal plant communities are unlikely to be able to migrate landwards in case of sea-level rise. This entails a squeezing of especially the uppermost vegetation zones.

Results

The regression models documented a locally dependent decreasing dominance of salt-tolerant species with elevation (adjusted R² = 66 - 68%). When projected onto the five sea-level-rise scenarios the linear regression models predict:

- A pronounced loss of salt-meadow area under the five future sea-level-rise scenarios (Fig. 2).
- The vegetation zones experiencing the most severe losses will be the middle and upper salt meadows, while the lower salt meadows will expand (Fig. 3).

Results

Figure 2. Percent salt meadow area lost under the five scenarios. Error bars indicate std. dev. Mean sea-level rise (SLR) is shown in brackets.

Conclusion

Future sea-level rises, especially if exceeding ~50 cm constitute a threat to salt-meadow associated biodiversity in Denmark:

- Sea-level rise will cause a restructuring of the salt-meadow plant communities.
- The pronounced loss of total salt meadow area is likely to entail a drastic reduction or even the loss of species or species populations characteristic to salt meadows.
- As the zones primarily lost are the middle and upper salt meadows the species known to inhabit these areas are especially at risk from future sea-level rise.

The Salt Meadow

Figure 3. A case study: The response of the four vegetation zones to the five sea-level-rise scenarios in a salt meadow on the island Mandø in the Wadden Sea, Western Jutland. Especially the middle and upper salt meadow will shrink, while the lower salt meadow will gain area.

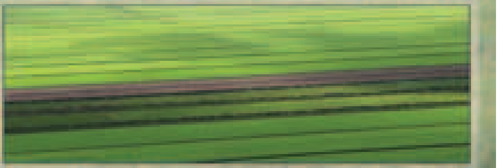
MADALGO – Center for Massive Data Algorithmics, a Center of the Danish National Research Foundation

Mapping of drainage ditches and density analyses

Fanney Ósk Gísladóttir, Jón Guðmundsson and Sunna Áskelsdóttir.
Agricultural University of Iceland

The network of drainage ditches in Iceland was digitized using SPOT 5 satellite images. The areal density of the network was then analyzed.

Background:
Icelandic peat-lands have been drained extensively. In recent decades. Considerable research have been done on wetlands and drained areas in Iceland. To interpret the results for larger areas, there has been a lack of information about the extent and location of drained areas and the drainage intensity is in each place.



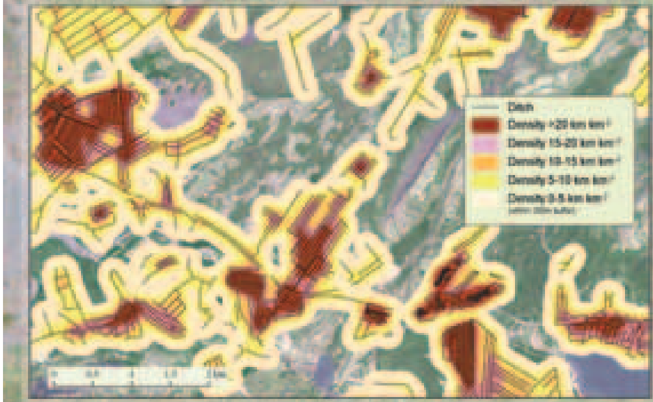
Methods
The ditches, visible on SPOT 5 satellite images from the years 2002-2007 were digitized. Their aerial density was analyzed in ArcGis using the Kernel density function. The function calculates density of linear objects (ditches) on square km. The output is a raster image (10x10 m) where each cell has a value depending on distance from ditches.

The dark colour represents high density of ditches and light colour a low density

SPOT 5 satellite image with digitized ditches. The area inside the box has not yet been digitized.

Results
Total length of digitized ditches is 29.700 km. The distribution of the ditches proved clustered, which reflect location of former wetlands and the position of farms. The highest density is usually closest to farms, where land has been drained for cultivation.

Areas where the density was less than 0,1 km/km^2 where left out. 111 km of ditches where thus excluded. The total area with density greater than 0,1 km/km^2, is 5837 km^2. Included in this number is land which was dry before the excavation of the ditches, and land were the ditches did hardly have any influence and land is still wet. The total area influence by ditches is accordingly overestimated. In other cases large areas have been encircled by ditches and part of the land drained not included in the total area due to distance between ditches. The area of drained land is thus underestimated.



Satellite image with overlaying classes of Kernel density analysis

Ditches in Iceland. Inside the box is an enlarged area showing details of the network.

More research is needed to relate the ditch density to drainage efficiency

Density km/km^2	***Area km^2***	***Ditches lenght km***	***% Ditches***	***% Area***
0,1-5	2930	1780	6,0	56,3
5-10	1346	11418	38,6	25,9
10-15	565	8466	28,6	10,9
15-20	261	5332	18,0	5,0
>20	101	2593	8,8	1,9
Total	**5203**	**29589**	**100**	**100**

Distrybutation of ditches density to equal interval classes

Conclusions
A digital map of all ditches and the density analyses gives various possibilities of utilization. For example it has been estimated in the national inventory of greenhouse gases, that the emission, due to wetland drainage is the largest single source of greenhouse gasses in Iceland. The present emission estimate is based on area as calculated from ditches length and estimated drainage efficiency. The density analyzed ditch map will make more accurate estimation possible. The map and the density analysis is also an important document for all research concerning wetlands and restoration of former wetlands.

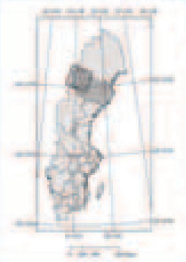
Multiple-scale classification of Swedish alpine vegetation from optical satellite data

Heather Reese, Anna Allard, Mats Nilsson, and Håkan Olsson
Department of Forest Resource Management
Swedish University of Agricultural Sciences (SLU)
Umeå, SWEDEN

Study objective

To classify alpine vegetation from medium-resolution optical satellite data using reference data from the National Inventory of Landscapes in Sweden (NILS), and to test the effect on classification accuracy due to variations in both the reference data and satellite data.

Study area



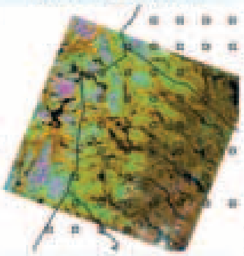
Satellite data

Three satellite data sources with varying spatial resolutions will be tested. This is of interest due to the heterogeneous nature of alpine vegetation types. Landscape characteristics and satellite data spatial resolution are also of interest in relation to the characteristics of the reference data to be used.

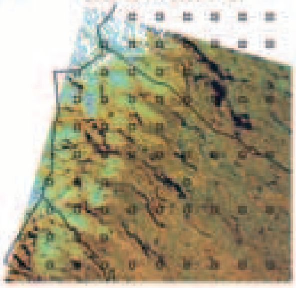
RGB display = NIR SWIR Red
NILS quadrats in black

SPOT-5 (10m pixels)
2006-08-19, 2004-07-25

Landsat-5 TM (25m pixels)
2006-08-19, 2005-07-31



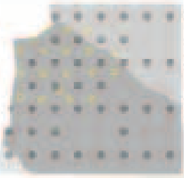
IRS-P6 AWiFS (60m pixels)
2006-08-17, 2005-07-31



Aerial Photography

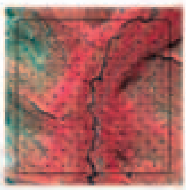
Reference data for the classification are taken from photo-interpretation of 1:30 000 stereo color-IR aerial photography.

In the adjacent figure, 5x5 km NILS photos are in black, while additional photos acquired in order to double the NILS sampling are yellow.



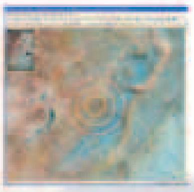
Point sample interpretation

For each of the 22 stereo pairs in the study area, a systematic grid of 110 sample plots will be photo-interpreted, resulting in a potential reference database of over 2000 samples.



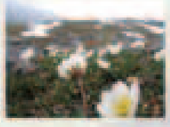
Multiple scale photo-interpretation

Vegetation type and percent coverage for 10m, 20m, and 30m radius plots are photo-interpreted.



Methods

Each satellite image source will be classified using the photo-interpreted reference data in a supervised classification. Three classification algorithms will be compared, namely Maximum Likelihood, Decision Tree, and Support Vector Machines. Variations on the reference data sets will also be investigated: a doubled NILS sampling scheme, the NILS sampling scheme, and other reduced sampling schemes. Classification accuracy will be assessed using photo-interpreted systematic sample plots from high-resolution (1:2000) color-ir aerial photographs.

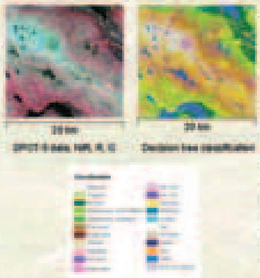


Vegetation Classes

The vegetation classes follow those established for the earlier photo-interpretation of the "Swedish Mountain Vegetation Map" (Ihse and Wastenson, 1975; Rafstedt 1982). These classes include bare rock, extremely dry heath, dry heath, mesic heath, moist/wet heath, grass heath, willow, alpine meadow, mountain birch with grass/herb field layer, mountain birch with shrub/moss/lichen field layer, coniferous forest, forested wetland, wetland (two types), snowbed vegetation, snow/ice, and water.

Current and Expected Results

The accuracy of a SPOT data classification derived using a decision tree algorithm was compared to that from maximum likelihood. Decision tree classification gave 86% accuracy using elevation derivatives + spectral data (75% using spectral data only) while maximum likelihood classification (spectral data only) gave 70% accuracy. The results indicate the utility of the decision tree classifier and the positive effect of combining spectral and elevation data. Classifications of Landsat and AWiFS are forthcoming.



20 km
SPOT-5 data, NIR, R, G

20 km
Decision tree classification

The results from photo-interpreting multiple-scale plots (shown at right) indicates the heterogeneity of vegetation types at 10, 20m and 30m radius areas. These plot radiuses also correspond to the satellite data pixel sizes, and give a preliminary indication about the utility of these satellite data sources for mapping of Swedish alpine vegetation. The satellite data classification algorithm, the characteristics of the reference data, the spatial resolution of the satellite data, and the heterogeneity of the landscape will all interact to have a combined effect on the classification result and accuracy.

The multiple scale photo-interpretation is of use in describing characteristics of the vegetation in the study area. The example below is based on half of the reference dataset. It can be seen that the 10m radius plot contains an average of 1.4 vegetation classes, while a 30m radius plot has on average over 2 classes. Classes such as low alpine meadow are examples of vegetation types that may occupy the majority of a 10m plot, while larger area plots contain on average ~50% or less of this cover type. Forest tends to be a more homogenous cover type, and is represented rather consistently within the three different plot sizes.

	10m radius		20m radius		30m radius		
Class label at center point	Mean % veg class in plot	Mean no. of veg classes in plot	Mean % veg class in plot	Mean no. of veg classes in plot	Mean % veg class in plot	Mean no. of veg classes in plot	Total number plots
Bare rock	72	2.1	50	2.8	45	2.8	23
Extreme dry heath	79	2.0	60	3.0	61	3.0	18
Low alpine meadow	82	1.7	52	2.4	44	2.8	87
Willow	84	1.6	66	2.2	59	2.6	83
Dry heath	88	1.5	77	2.0	71	2.3	79
Mesic heath	84	1.5	63	2.2	57	2.4	122
Grass heath	84	1.4	73	1.9	68	2.5	56
Wetland	86	1.4	74	1.8	73	2.1	116
Mountain Birch (herb/grass layer)	91	1.2	84	1.6	82	1.7	112
Snowbed Veg.	93	1.2	84	1.7	82	1.8	33
Mountain Birch (shrub layer)	95	1.1	88	1.4	87	1.6	208
Total Weighted Average	**87%**	**1.4**	**74%**	**1.9**	**70%**	**2.1**	**954**

This project is part of a PhD dissertation, with funding from the Swedish National Space Board and the Swedish Environmental Protection Agency.

Role of Wind Activity in the Degradation of Soils and Forest Opening in the Northern Portion of the Closed Boreal Forest, Québec, Canada

A. Robitaille[1]
A. Leboeuf[1]

Introduction ❶

- Wind degrades soils and contributes to forest opening on some suitable lands to aeolian action.
- Fire is the triggering factor.
- Deflation requires strong wind, dry and fine surficial deposits, absence of soil vegetation layer and low phreatic level.
- Sand dunes allow a past climate reconstitution.

Sand dunes in Southern Québec and study areas ❷

Study areas :

- Rivière Eastmain
- Lac Nosaccane
- Rivière Péribonka
- Lac Piétipi
- Rivière des Montagnes Blanches
- Lac Opocopa
- Lacs Éric - Fournier
- Lacs aux Sauterelles–Thévet
- Rivière du Petit Mécatina

Wind activity ❸

❹ Methods and results

Dynamic of the great sand dune

Blowouts and deflation pavements

In sector 8, soil exposed after fire are affected by strong wind from west, south-west and north-west

Edge showing a reactivation of aeolian action in deflation basin

There is thousands of blowouts and deflation pavements contributing to losses of productive forest areas and forest opening.

❺ Conclusions

Aeolian activity :

- Is in progression for study areas affected by fire.
- Contributes to forest opening for these latitudes. Since ?
- Fire and surficial deposits maps can locate sensitives areas.

Ongoing studies:

- Calculate area of bare surfaces following fire at a regional scale and assess its impact on forest opening over time.
- Date the great sand dune evolution from sector #7 to reconstitute regional paleoclimate.
- Mapping the temporal changes of microtopography of deflation basins and sand dunes from sector #7.

❻ References

Method Proposal : Integrated Ecoforest Mapping of the Northern Portion of Boreal Zone, Québec, Canada

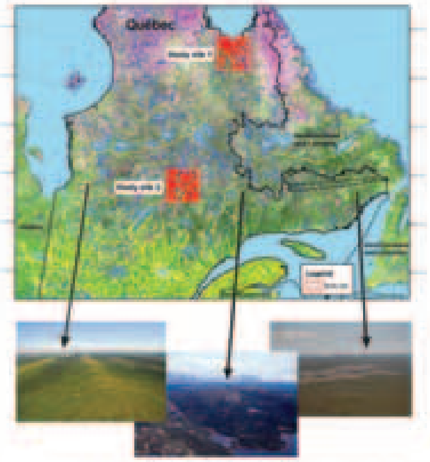
A. Robitaille[1]
A. Leboeuf[1]

[1] Ministère des Ressources naturelles et de la Faune du Québec

Introduction ❶

Since 2000, new needs emerged for ecoforest information in data-poor area located in northern boreal zone.

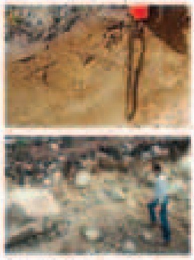
Study area and sites ❷



Altitude, relief, geology, surficial deposits, vegetation and climate change greatly over the whole boreal zone.

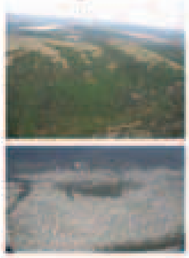
Classification structure ❸

Surficial deposit



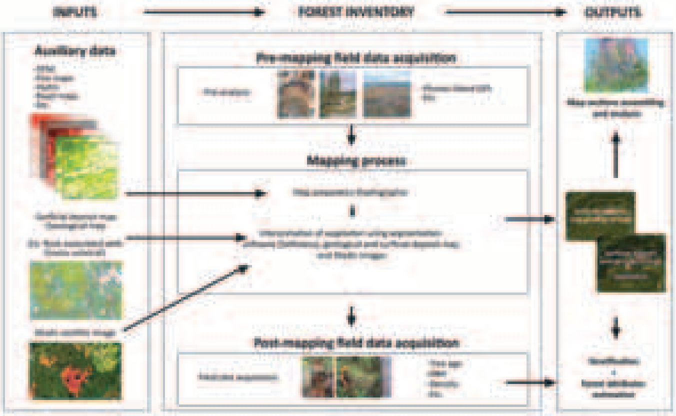
Genetic classification
1. Glacial
2. Glaciofluvial
3. Fluvial
4. Lacustrine
5. Marine
6. Coastal
7. Organic
8. Hill and Weathering
9. Aeolian

Vegetation

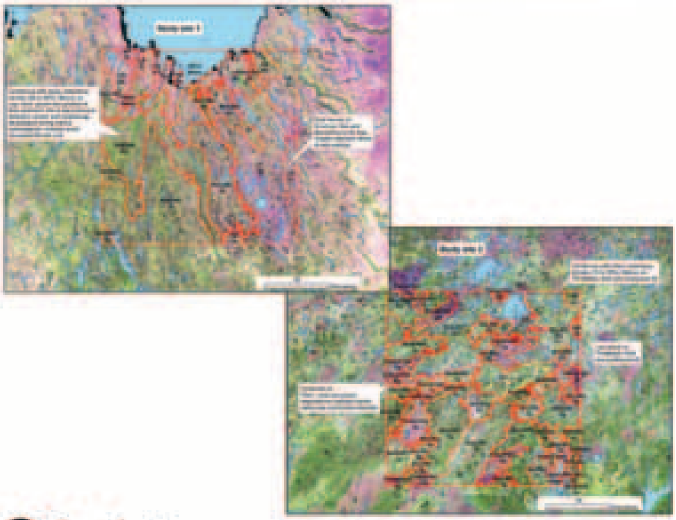


1. Cover type
2. Understory vegetation
3. Density class
4. Disturbance
5. Age class
6. Vegetation without forest potential
7. No vegetation

❹ Approach



❺ Preliminary results for sites 1 and 2



❻ Conclusions

Advantages

- Forest overview of a huge territory
- Describes ecological information available: geological and surficial deposits, perturbations, etc.

Limits

- Some attributes are not mapped, (e.g. height, species) or were difficult to discriminate

Québec

Classification System for Vegetation Mapping in Iceland

Rannveig Thoroddsen – The Icelandic Institute of Natural History

Introduction

The structure of plant communities in Iceland as defined by the botanist Steindór Steindórsson about 50 years ago is still the basis of vegetation mapping in Iceland. However, the legend for the vegetation mapping has been slightly revised and simplified through the years.

Steindórsson based his vegetation classification on the procedure of plant sociology, using a floristic method where the basic floristic unit is the "association".

Plant communities were organized into a hierarchical classification from the simplest unit, sociation (*gróðurhverfi*) to the most composite unit, order (*gróðurlendi*).

Vegetation Mapping

The original purpose of the vegetation mapping in the 1950s was to determine the sheep carrying capacity of the ranges of the Central Highlands. Since 1995 the main emphasis has been to revise previous vegetation maps as a basis for environmental impact assessments.

Vegetation Classification

There are six main vegetation complexes: Dry land vegetation, wetland i.e. fringes, sloping fens, level fens, aquatic vegetation and sparsely vegetated land. The vegetation complexes are divided into 16 orders and 98 sociations. Sparsely vegetated land (<10% veg. cover) is divided into 14 substrate types.

Legend for the Icelandic Vegetation Maps

Moss heath. Mosses cover more than half of the area. Organic layer is thin. On windy places with high precipitation *Racomitrium* spp. are dominant mosses. Vascular plants are few and scattered. In snow patches *Anthelia* spp. are dominant mosses. One order divided into ten sociations.

Fig. 1. Racomitrium lanuginosum on lava (A1h).

Fig. 2. Moss heath with Racomitrium spp. (A1) and Anthelia spp. (A9).

Heathland. Found on rather dry soil with hummocky surface. Dominant growth forms or species: ericaceous dwarf shrubs, *Betula nana*, *Salix* spp., *Kobresia myosuroides*, *Juncus trifidus*, *Carex bigelowii* and lichens. Seven orders divided into 19 sociations.

Fig. 3. Heath vegetation dominated by ericaceous dwarf shrubs (B4).

Fig. 4. Lichen heath and dwarf shrubs (J1).

Grassland and forb meadows are on well drained, thick and often fertile soils. *Festuca* spp., *Agrostis* spp., *Deschampsia caespitosa* and *Anthoxanthus odoratum* dominate grasslands. Various species of tall and low forbs dominate forb meadows. Includes two orders divided into ten sociations.

Fig. 5. Grassland (H1).

Fig. 6. Forb meadow (L2). Geranium sylvaticum, Ranunculus acris, Alchemilla filicaulis and Bartsia alpina.

Wood- and shrubland. Birch (*Betula pubescens*) is the only native tree that forms continuous woodlands in Iceland. Low birch shrubs and *Salix phylicifolia* are dominant species in shrubland. Includes two orders divided into three sociations.

Fig. 7. Birch wood (C5).

Fig. 8. Cultivated land. Golf course (R2), pastures (R3, R4), reforestation (R6).

Cultivated vegetated land has been plought and the vegetation has been sown or planted. Vegetables, grasses, corn and fodder are examples of cultivated crops. Reforestation is also part of cultivated land. Includes one order divided into six sociations.

Wetland. Water saturated soils. Wetland includes fringes (moist land), sloping mires, level fens and vegetation of lakes and ponds. Includes four orders divided into 45 sociations.

Fig. 9. Level fen. Carex rostrata (V2) and Eriophorum angustifolium (V3).

Fig. 10. Sloping fen with Carex nigra and Salix spp. as dominating species (U2).

Sparsely vegetated land is divided according to the underlying substrate, such as gravelly flats, river-plains, lava, cliffs, etc. Non-vegetated cultural land (e.g. roads, buildings, mines) are also included within this category. There are 14 substrate types.

Fig. 11. Gravelly flat (me) at the front and rocks (gt) surrounded by pumice (vi).

Fig. 12. Hydrothermal clay (hvl) and lava (hr) in the background.

Mapping and Monitoring of Nordic Vegetation and Landscapes
Nordic Conference in Iceland 16th – 18th September 2009

Shoreline Erosion and Aeolian Deposition along a recently formed Reservoir, Blöndulón, in Iceland

Olga K. Vilmundardóttir[1,2], Borgþór Magnússon[1],
Guðrún Gísladóttir[2,3] and Þröstur Þorsteinsson[3]

[1]The Icelandic Institute of Natural History, [2]Department of Geography and Tourism, [3]Institute of Earth Sciences, University of Iceland

Introduction

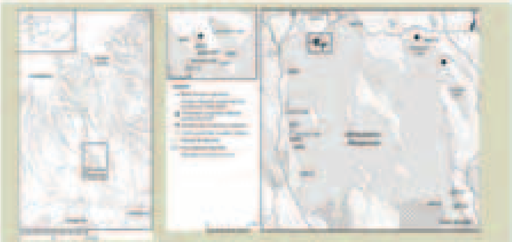
The formation of hydro-electric reservoirs leads to a range of environmental changes. Direct impacts are related to geomorphologic processes that become active: erosion, sediment transport and deposition. These processes are mostly wind-induced by the generation of waves with subsequent shore erosion and aeolian activity and sediment deposition. The aim of this research was to measure and describe erosive processes occurring along the shoreline of the Blöndulón Reservoir, northern Iceland, in context with landscape, geomorphologic properties of bluffs and hydrodynamic conditions.

The Blöndulón Reservoir

The 57 km^2 reservoir was formed in 1991 in the glacial river Blanda and enlarged in 1995. It is rather shallow with mean depth of 7,6 m. The water level fluctuates and the annual drawdown reaches up to 12 m. The area lies 400–600 m a.s.l., the climate is semi-arid with a mean annual precipitation of 400 mm. The area is windy, dominated by southerly and northerly winds. During summer, dry storms with a south-easterly direction are most frequent with wind speeds up to 20–30 m s^{-1}. At the Kolka automatic weather station, located by the reservoir, continuous measurements on temperature, precipitation, wind speed and direction have been made since 1997.

Methods

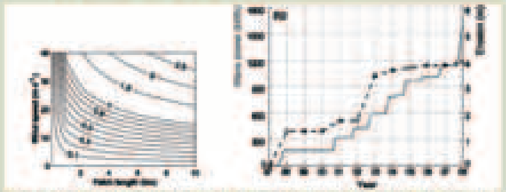
Bluff erosion was measured at 16 locations, at one site since 1997 and at all sites from 2004–2008. The distribution of aeolian material was mapped at the monitoring sites, starting in 1998, and along the entire reservoir in 2007. Field observations, GIS analysis, calculations of wave power and meteorological data were used to measure and describe the erosive processes occurring along the new shoreline.



The Blöndulón Reservoir in northern Iceland and sites of measurements.

Bluff erosion

Bluff development is mainly determined by the available energy and limitation in material supply. On the basis of the combined factors, the bluffs varied in their erosion phase. After the formation of the reservoir the most rapid initial erosion rate occurred on bluffs on the northern and western shores, at sites with glacial till substrate, high cumulative wave power, and long fetches along the dominant wind direction. The boulders and cobbles from the eroded substrate armoured the shore from further wave erosion, creating a relatively stable bluff. In recent years, relatively high erosion rates have continued at bluffs of fluvioglacial material under low cumulative wave power. The fluvioglacial material has low resistance to wave activity, creating unstable bluffs, whereas bluffs made of glacial till are more stable.

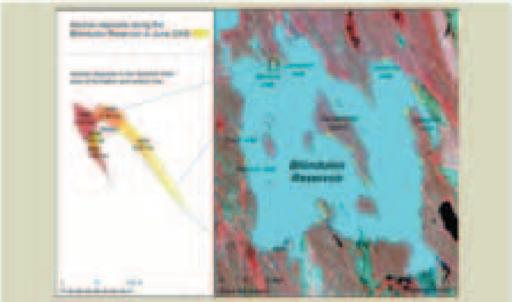


The wave height model where wave height is a function of wind speed and fetch length. Cumulative wave power was calculated for each erosion transect and compared to the cumulative bluff erosion.

A relatively stable bluff (R0) made of glacial till (left) and an actively eroded bluff of fluvioglacial sediments (R15).

Aeolian deposition

Aeolian deposits are controlled by wind, availability of aeolian source material and local morphology. At the Blöndulón Reservoir we found that sites of frequent aeolian deposits were inlets open towards the south where the material deposited on gentle slopes. Slope and aspect against wind direction restricted the distribution. By 2008 the deposits covered 0,21 km^2 of the heathland along the reservoir, with a total volume estimated at 11 000 m^3. Aeolian deposits, originating mostly from tephra beds eroded by wave action, were thickest in heathland near the shore, where repeated deposition has occurred in inlets of low wave energy.



The distribution of aeolian deposits along the reservoir and an example of an inlet of repeated deposition.

Water level and erosive processes

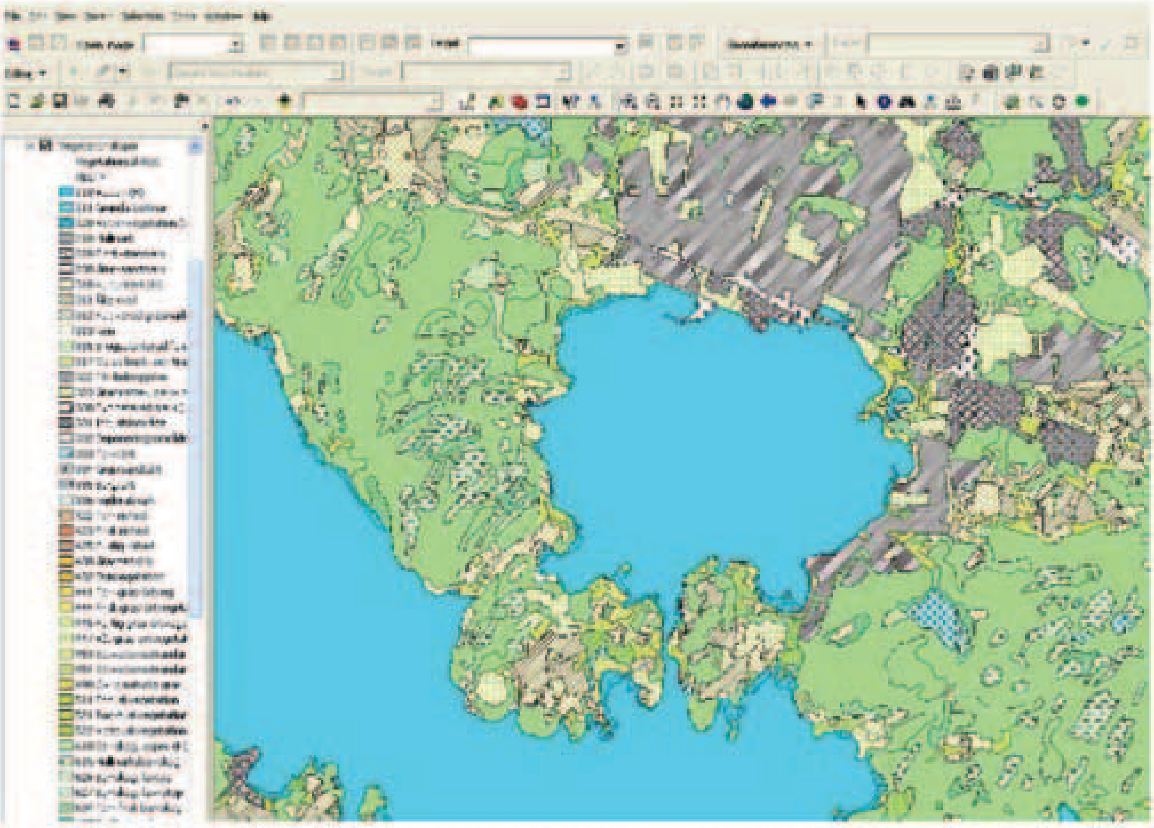
Bluff erosion and aeolian reworking of sediments are closely linked to water level fluctuations. Bluffs are developing towards equilibrium but erosion is highly dependent on storms occurring under high water levels. The morphologic development of the shores of the reservoir has generally been governed by the resistance of the substrate material to wave action, fetch length, storm direction and frequency, and subsequent wave energy. Aeolian deposition is a result of bluff erosion, sediment transport into inlets of low wave energy, and dry strong winds.

The research was funded by Landsvirkjun and the Icelandic Research Fund for Graduate Students.

Mapping and Monitoring of Nordic Vegetation and Landscapes
Nordic Conference in Iceland 16th – 18th September 2009

A GIS study to assess valuable shore habitats using vegetation data

Selection of vegetation types from the vegetation database that corresponds to high value habitats and general value habitats in perspective of biological diversity.



A part of the vegetation database of the, province of Värmland, in the western part of Sweden.

Presentation of the selected polygons of the important habitats and buffer lines that shows the 100, 200 and 300 meters distances from the waterside.